THE JOURNAL OF
PROSTHETIC
DENTISTRY

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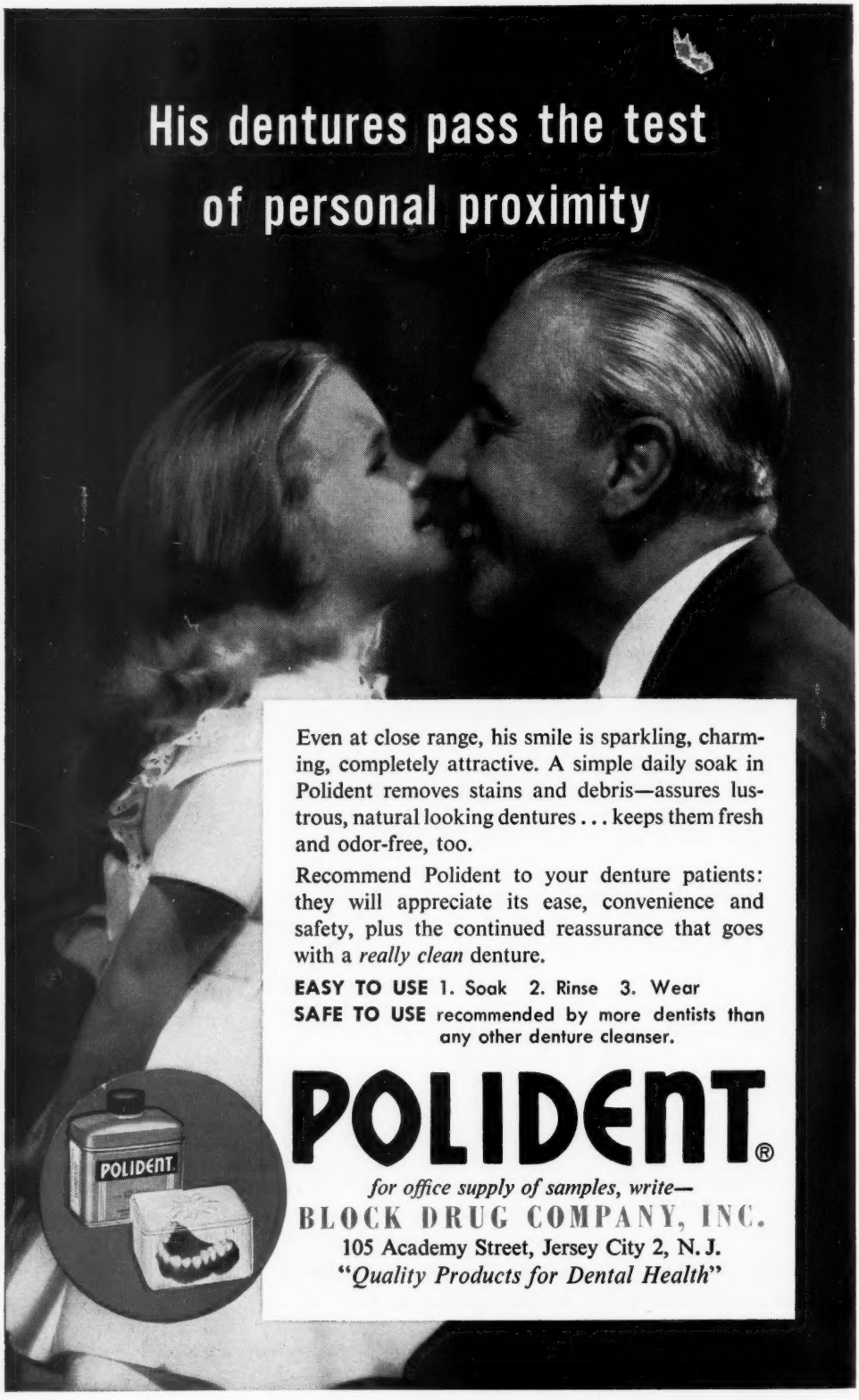

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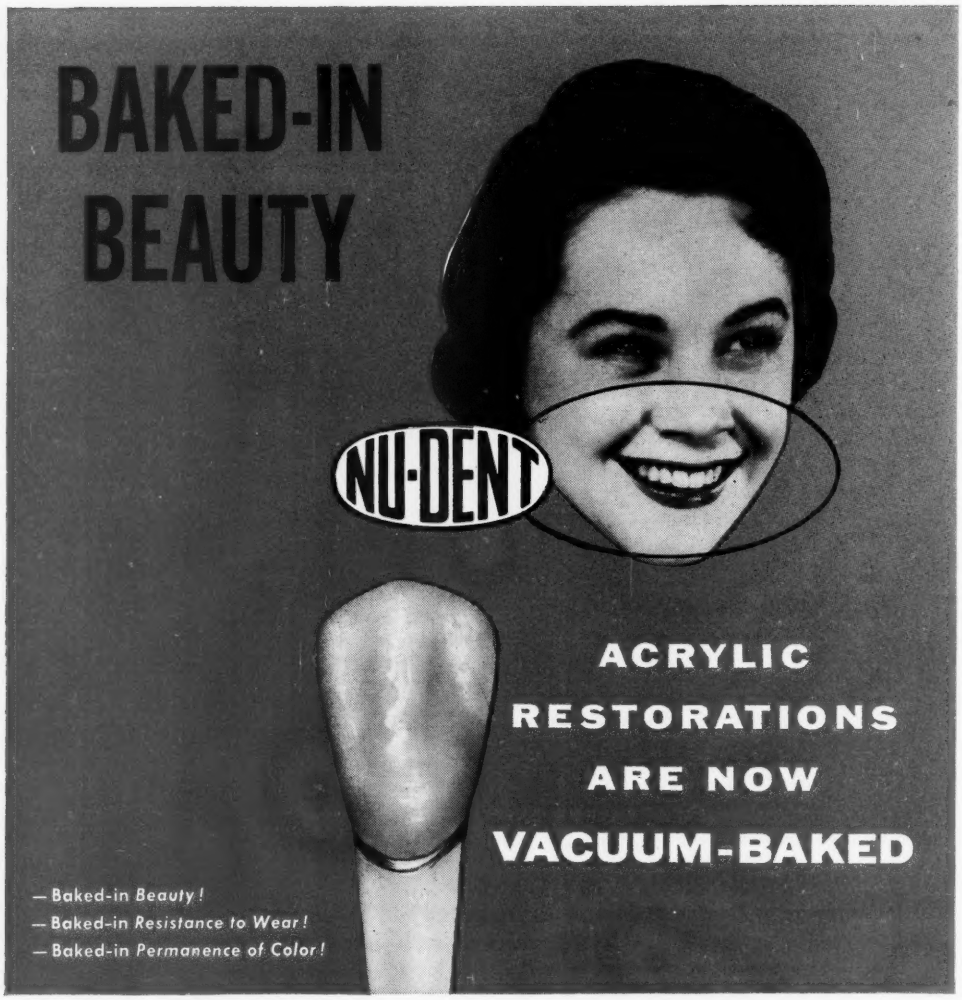

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THE JOURNAL OF
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SEPTEMBER-
OCTOBER
1960
VOLUME 10
NUMBER 5

THROUGH THE EYES OF THE EDITOR

The Principles, Concepts, and Practices Committee of the Academy of Denture Prosthetics reports additional statements approved by 85 per cent of the Fellowship of the Academy. These statements, together with those contained in the first report (J. PROS. DEN. 9:528-538, 1959), represent real progress toward a uniform understanding of standards for complete denture techniques.

Stanley J. Behrman discusses the implantation of magnets in the jaw to aid in the retention of complete dentures and describes the technique for their use. He reports his experiments with implants in animals as well as with denture patients and shows the progress toward his current technique. Apparently, the magnets can be retained in the jaw as implants if the surgical and prosthodontic techniques are properly carried out. The long range value of magnets for retention of dentures is still being studied. Further time and experimentation will determine the best methods for their use. The technique used for the construction of the dentures should be as accurate as possible in order to avoid difficulties other than that of lack of retention.

Thomas E. J. Shanahan and Alexander Leff report their tests of the accuracy of wax as a recording medium for interocclusal records. They found that the resiliency of the wax prevented these records from being reliable. They suggest that cold-curing acrylic resin is a better material for this purpose and describe a technique for its use. The acrylic resin can be adapted into an interocclusal record which requires a minimum of closing pressure applied by the patient. This seems to be to a very great advantage in the construction of complete dentures because it would cause minimal displacement of the recording bases.

Victor O. Lucia discusses the theory of centric relation and its application in practice. He considers the location of rotational centers essential to the location of centric relation and describes his method of locating centric relation and the rotational centers of movement of the mandible. It seems sound to depend upon centric relation as a constant reference relation for establishing the occlusion.

A. O. Chick reports his studies of right and left lateral protrusive and retrusive mandibular movements by means of a new technique. The method he used is ingenious, and other applications of it may be made. The results indicate that mandibular movements made while the teeth are in contact are rotary, as has been suggested by some other authors.

Don N. Brotman continues his discussion of mandibular hinge axes. He suggests mathematical formulas for determining the amount of error. He points out the importance of the transverse hinge axis as a means for locating centric relation and recognizes the errors which are possible if the axis is located by means of an "arbitrary" face-bow. He suggests that errors in orientation of casts on the

articulation may be difficult to detect clinically, but this does not mean that they are unimportant.

Heinz O. Beck discusses the selection of an articulator and the jaw relation records for adjusting it. He recognizes limitations of various types in all articulators and suggests that these limitations must be recognized if errors produced by the articulators are to be avoided. This seems to be sound because any motion of the parts of an articulator is produced by the dentist's or technician's power and control. The articulator can do only what the person using it does with it, even though the instrument can serve to limit the action.

Joseph S. Landa discusses oral hygiene, chemicotoxicity, nutrition, allergy, and thermal conductivity as causes of inflammation under dentures in this part of his series of articles on trouble shooting in complete denture prosthesis. He points out the means for a differential diagnosis between these possible causes of inflammation. This is an important phase of denture service which is overlooked by sponsors of "denturist" movements. Only those thoroughly trained in the biologic sciences (dentists) are capable of making this differentiation. The thorough comprehension of the factors involved in this phase of diagnosis is another example of the daily use of the biologic sciences in prosthetic treatment.

Oliver C. Applegate discusses the decisions involved in designing removable partial dentures. A few of these are mechanical in nature, but *most* of them involve judgment regarding anatomic and physiologic factors. These are factors that only a dentist can know. On the basis of his knowledge, he decides which teeth are to be saved and by what means they are to be treated. It is obvious, therefore, that dentists design partial dentures even though laboratories may determine the positions of clasp arms on the teeth on casts of the partially edentulous mouth. He suggests an extension of the Kennedy classification to cover some situations that were not covered under the original classification. Properly used, this new classification can aid in the evaluation of the factors which determine the choice of denture design.

Luzerne G. Jordan urges close cooperation between prosthodontists and periodontists in the treatment of selected patients with advanced periodontal disease. The modification of the occlusion and the bracing supplied by a removable partial denture can assist in saving teeth which otherwise would be lost. Good judgment and careful design and treatment are essential to the success of this therapy.

Frank E. Jeffreys and Robert L. Platner discuss the factors involved in developing occlusion with partial dentures. They recognize the importance of harmonizing the total occlusion with the temporomandibular joints and the neuromuscular system. They suggest a sequence of steps in the procedures which can develop the proper relationship between all of the factors. A simple central bearing device is used as an aid in developing the desired occlusion. If this is used intelligently, it can be of great value.

George H. Moulton considers the tooth occlusion that occurs in the posterior terminal hinge position (centric relation) as centric occlusion. This concept may appear to differ from that of many others, in that the occlusion may be harmonious or not. The first point of contact as the jaw closes in centric relation may or may not be a uniform contact. If this contact is not uniform (balanced), an analysis of the occlusion will point the way to the proper treatment. This seems to be a sound approach to the problem. However, it may be easier for some to think of jaw relations as bone-to-bone relations and to think of occlusion as tooth-to-tooth relations. The same end result will be achieved with this concept if the occlusion is made to harmonize with the centric relation of the mandible to the maxillae. In either concept, there must be harmony of the occlusion with centric relation and the neuromuscular system. In one concept the emphasis is upon the error (so the error can be eliminated), and in the other the emphasis is upon the objective of building harmony between *all* of the factors of occlusion (regardless of the error).

Michael Turoff suggests two methods for making jaw relation records and maintaining them while the restorations for occlusal rehabilitation are being constructed. A "record" denture is constructed for patients who have partially edentulous ridges without posterior abutments. "Transfer tables" are constructed for patients who have most of their teeth. Both methods furnish a firm foundation for the interocclusal records, and they should produce accurate results. The fact that these

temporary sturctures can be used by the patients as temporary restorations is an advantage.

Zvi L. Abramowsky describes his technique for making fixed partial dentures by casting them in one piece. He claims a number of advantages for the procedure, but it is obvious that considerable care and skill must be used to avoid defects. One faulty margin could spoil the entire restoration. He uses guttapercha as the temporary cover for the prepared teeth. If this were left on the teeth too long, the periodontal ligaments would be endangered. The procedure would save time provided every step was accurately carried out.

Earl H. Shatzkin and Martin Edelmann describe a simple technique for temporary splinting of mobile anterior teeth. The appliance will serve its purpose for a short time, but it does add to the danger of dental caries in the splinted teeth.

Robert H. Sacherman describes his technique for making a cast-gold splint to stabilize mobile anterior teeth. The splint is attached to the lingual surfaces of the teeth by means of pins. This appliance should accomplish its purpose, but it certainly increases the danger of dental caries. It would be difficult to detect a failure of cementation on any one of the units of the splint.

William H. Pruden II describes his technique for making a gold crown with a veneer of porcelain. The veneer is in reality a porcelain inlay in the crown. The restoration has strength and permanence of form and color. The color can be controlled more easily than the color of porcelain baked on gold.

Samuel Levine describes a technique for making gold crowns which makes use of gold instead of copper bands. The gold band is adapted to the prepared tooth and reinforced with cold-curing acrylic resin; the pattern is built up with wax. The procedure eliminates many laboratory steps and is almost a "direct" technique.

Maury Massler and Nirmala Mansukhani report their laboratory research on the permeability of various cavity liners to several cement liquids. Almost all of the liners tested were found to be effective, but in varying degrees. The method of testing supplies some of the answers to the problem, but it should be noted that the method does not duplicate exactly the action of the liners on dentine.

Grant Van Huysen reports his studies of sclerosed dentine by means of x-rays and histologic sections. He shows that roentgenograms can be used to diagnose sclerosed dentine.

L. S. Pettit, Benjamin H. Williams, and Robert M. Ryan report their treatment of a child after a hemimaxillectomy. This is an excellent example of the important role of prosthodontics in assisting in the maintenance of the health of patients.

Cicero Brito Vianna describes the prosthesis he constructed for a patient who lost both of his ears. This is a good example of the adaptation of dental methods and materials to surgical prosthesis.

Louis F. Bishop discusses the relationship between cardiologists and prosthodontists, and it is apparent that this is another facet of the prosthodontist's responsibility that is not mechanical. The various causes and symptoms of heart disease are discussed with suggestions about emergency treatment.

—Carl O. Boucher

COMPLETE DENTURES

PRINCIPLES, CONCEPTS, AND PRACTICES IN PROSTHODONTICS

Progress Report II

THE ACADEMY OF DENTURE PROSTHETICS, 1960

THE FIRST REPORT OF THIS COMMITTEE, published in the July-August, 1959, issue of THE JOURNAL OF PROSTHETIC DENTISTRY, contained 164 statements. This 1960 list adds 39 more statements. Future reports will contain further additions and revisions.

In English and through translation, the suggestions of the committee have been met with cordial response from editors and others all over the world.

As stated in the first report, "The readers' comments regarding this project would be welcome," especially the submission of additional statements on matters which might guide prosthetic workers along safe paths.

STATEMENTS OF PRINCIPLES, CONCEPTS, AND PRACTICES IN COMPLETE DENTURE SERVICE: PROGRESS REPORT II

IMMEDIATE DENTURES

Before deciding on an immediate complete denture, the desirability of a partial denture—either fixed or removable—should be carefully considered.

"Before and after" photographs of the patient's face are often valuable.

Oral and printed information for the patient is especially useful in immediate denture service.

Properly constructed and adjusted immediate dentures generally form better ridges than those which develop when healing is allowed to occur in the absence of dentures.

An immediate denture should not be constructed unless adequate occlusion of the posterior teeth is assured.

Immediate dentures should be made primarily for patients who understand the requirements and are willing to cooperate with the dentist.

Alginate materials are useful in making the impressions for immediate dentures.

Alginate and similar materials may produce overextension of the flanges of dentures when oversized stock impression trays are used.

Facial templates or other facial measurements should be made before the natural teeth are removed.

To improve major facial deformities, it may be advisable to make surgical provision for the proposed teeth.

The posterior teeth should sometimes be removed first. Time should elapse to allow partial healing of the tissues in the posterior part of the mouth before immediate dentures are made.

When only the natural anterior teeth remain, the artificial teeth should be set on baseplates and tried in the patient's mouth to check jaw relation, tooth occlusion, and appearance.

Conservative surgical procedures with minimum trauma provide the best denture foundations.

Postoperative swelling and discomfort may be minimized by not retracting the gum tissue excessively at the time of tooth extraction.

If the frenum is resected, the denture flange should be kept thin in this region to avoid obliterating the philtrum.

Usually the dentist should conserve as much healthy bone as possible when removing the teeth, merely smoothing any sharp projections of bone.

Vertical dimension and horizontal jaw relation as indicated by the natural teeth should be critically examined before acceptance for the immediate dentures.

The median line for the proposed dentures should be marked on the cast before the natural teeth are removed.

Some of the malocclusions present after the immediate denture has been placed may result from swelling or resorption of the tissues. The swelling is usually temporary and largely unavoidable; the shrinkage should be compensated for with the use of suitable relining material.

Patients should be cautioned against vigorous chewing during the initial wearing period.

There is danger of extensive bone resorption under immediate dentures unless such factors as vertical dimension and balanced occlusions are controlled.

Study casts are particularly helpful in conjunction with immediate dentures for diagnosis, planning, and patient education. The casts may be filed along with the other records.

When the natural posterior teeth have been removed and the anterior ones still remain, it is important to make the jaw relation records under minimum closing pressure on accurately fitting bases.

When it is desired to duplicate the arrangement of the natural teeth, the teeth of the cast should be removed singly so that the adjacent teeth serve as guides.

A complete immediate upper and a distal extension partial lower denture in the same mouth may require repeated relining of the lower denture bases and sometimes also the anterior part of the upper denture base to maintain the desired orientation of the occlusal plane.

The patient should be scheduled to return to the dental office at stated intervals after the immediate denture has been placed, at which times flange extensions, tooth occlusions, tissue irritation, etc., should be checked.

PREDENTURE CONSIDERATIONS

Oral and printed information should be available to the patient before denture construction is agreed upon and undertaken.

CASTS

Suitable means should be employed to prevent baseplate and other materials from adhering to or injuring the casts.

The cast produced from an impression should record accurately the form and dimensions of the impressions, including the height and thickness of the flanges.

Prolonged soaking in water of a cast made of gypsum material results in disintegration of the cast surface.

CENTRIC JAW RELATION

Subtile or gross changes in the position of the mandible may result in vertical, lateral, or anteroposterior shifting when deflecting occlusal surfaces initiate continued abnormal reflex stimuli.

Rest relation of the mandible is a relatively stable condition and the one to which the patient can return if not under undue tension.

Centric jaw relation should be recorded at the vertical jaw relation to be used in constructing the dentures.

If the posterior teeth have been missing and mastication has occurred only on the anterior teeth, the equilibrium of the mandible may have been lost, and it should be restored before the denture construction is completed.

FACE-BOW RECORD

A face-bow should be used for mounting the upper cast on any articulator with a fixed opening axis.

ARTIFICIAL POSTERIOR TEETH

The dentist should consider the advisability of occluding resin teeth against porcelain teeth.

DELIVERY OF THE DENTURE TO THE PATIENT

On delivery of the denture, the dentist should make a record of the nose-to-chin distance with the teeth in occlusion so that he can compare this with any subsequent nose-to-chin distance.

POSTINSERTION DENTURE SERVICE

More extensive resorption is expected when natural teeth have been lost because of periodontal disease than when the teeth have been lost from other sources.

Newly relined dentures should be mounted on an articulator for inspection and refinement of the occlusions.

1959 TO 1960 COMMITTEE ON PRINCIPLES, CONCEPTS, AND PRACTICES IN PROSTHODONTICS

FRANK M. LOTT
S. HOWARD PAYNE
VICTOR H. SEARS, CHAIRMAN

646 WASHINGTON ST.
VALLEJO, CALIF.

THE IMPLANTATION OF MAGNETS IN THE JAW TO AID DENTURE RETENTION*

STANLEY J. BEHRMAN, D.D.S.**
New York, N. Y.

MAGNETS HAVE BEEN IMPLANTED IN THE MANDIBLE and have been retained successfully for more than 7 years as an aid in the retention of complete dentures. The attraction between the magnets implanted in the jaw and similar magnets placed in an otherwise conventional complete denture helps retain the denture in position (Fig. 1). This method was introduced to the dental profession in a Scientific Exhibit at the Annual Session of the American Dental Association in 1952,[1] approximately 6 months after the completion of the first successful implantation. Now, 8 years later, a definitive developmental, technical, and follow-up report is presented.

Today, the majority of edentulous patients can be fitted with dentures that are functional, comfortable, esthetic, and secure. Yet, there are a number of patients for whom conventional prosthetic techniques are inadequate. The profession's desire to aid this group of people has produced a plethora of retentive devices (springs, suction cups, repelling magnets, etc.) and myriad adhesive powders, gums, and ointments. All of these have proved unsatisfactory.

Particularly intriguing have been those attempts to implant a "toothlike" structure into the edentulous jaw. Since the first effort by Maggiolo[2] in 1809, innumerable investigators have tried devices made of platinum,[3] iridium,[4] silver,[5] porcelain,[6] and other materials. These methods have resulted in failure and extrusion of the implant, and with good reason.

Physicians have been implanting nonviable substances into the body since 1565. During the ensuing years, several fundamental principles of implantation have been evolved[7]: (1) The implant must be made of tissue-tolerated material. (2) The implant must be completely covered by tissue. (3) Bone-bearing implants must be immobile[8]—bone resorption is directly proportionate to implant mobility; mobility, tolerance, and bulk are interrelated. (4) The implant must not interfere with the physiologic state of the adjacent tissue.

Every attempt to circumvent the principle of *complete coverage* for more than a brief span of time has resulted in failure. In ophthalmologic surgery there has been a particularly acute correlation with the exposed type of dental implants. Using eye implants very much akin to exposed dental implants,[9-11] ophthalmologists

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Presented before the New York Academy of Prosthodontics in New York and the American Denture Society in Chicago.

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discovered that regardless of the materials used—Vitallium, tantalum, and tissue-tolerated plastics—and regardless of antibiotic coverage, every type of exposed eye implant failed.[12-15] It seems unlikely that incompletely covered dental implants, transmitting masticatory stresses to the underlying bone, can be completely successful.[16,17]

The solution, it appears, would be to get something into the jaw which can be covered completely, which will not interfere with the physiologic state of the tissue, and yet which can transmit a retentive force to the denture. The only material which can be covered completely, yet transmit force through this covering, is a magnet.

The theory as it was evolved in 1948 was simple: implant a magnet in the jaw, covering it completely with tissue, and place a magnet in the denture; the attractive force between the magnet in the jaw and the magnet in the denture would pass through the covering tissue and would help hold the denture in place (Fig. 1).

Although the theory was simple, several basic problems had to be answered: (1) Could magnetic material be implanted safely into the jaw? (2) Would the force obtained be adequate to aid in denture retention? (3) Could a simple, safe, and inexpensive surgical technique be evolved? (4) Could current denture construction methods be employed? (5) What would be the long-term reaction of the tissues to this method?

Could Magnetic Material Be Implanted Safely Into the Jaw?

TISSUE-TOLERATED MATERIALS

A review of the literature available in 1948 indicated that certain stainless steels,[18] Vitallium,[19,21] tantalum,[22-24] methyl methacrylate,[25-32] and polyethylene[33,34] could be implanted safely in bone. These implants fulfilled the first principle of implantation in that they were made of tissue-tolerated materials. Their successful implantation was predicated on observance of the other long-established principles. Unfortunately, none of these materials had any appreciable magnetic properties. None of the plastics, and neither Vitallium nor tantalum, could be magnetized. The amount of magnetic flux which could be induced in tissue-tolerated stainless steels was insignificant. Some other magnetic material had to be found.

MAGNETISM AND MAGNETS

For purposes of this presentation, magnetism can be described by its property of attracting magnetic substances.[35] The origin of magnetism in certain materials is attributed to spinning electrons within the third incomplete shell of the atoms. These spinning electrons create a magnetic moment. In unmagnetized magnetic substances, these moments are oriented randomly and neutralize one another (Fig. 2, *A*). When an external magnetic field is applied, it produces parallel alignment of the moments and the material is magnetized (Fig. 2, *B*).

In certain substances, the application of a small external field can produce magnetic alignment. When the external field is removed, however, very little of the magnetism remains. These substances are "low-energy" or "soft" magnetic

materials. Other magnetic materials, because of restraining forces within them, require the application of large external fields to reorient the spinning electrons. Because of these same restraining forces, when the external field is removed, the electrons remain in their new alignment. These materials are "high-energy" or "hard" magnetic materials and are used in permanent magnets.

More familiar than spinning electrons is the graphic representation of the field of force produced when iron filings on a sheet of glass are placed over a magnet (Fig. 3).[36] These illustrated lines do not actually exist as such. Magnetism does not consist of lines, or waves, or rays—its precise form is unknown. Nonmagnetic materials are completely pervious to magnetism. Magnetism will pass through water, plastic, skin, bone, etc., and will have no effect on these substances. Magnetism is completely innocuous to tissue. Scientists who have worked with magnets all of

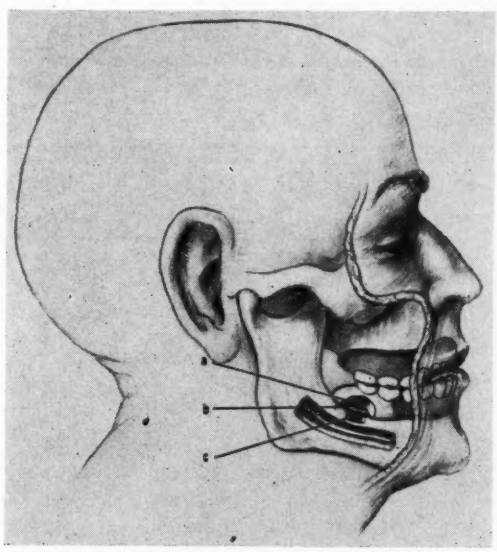


Fig. 1.—*(a)* The denture magnet in the denture; *(b)* the covering mucoperiosteum; *(c)* the implant magnet in the mandible.

their lives have experienced no deleterious effects from magnetism. Similarly, men who have worked with powerful electromagnets have never had any ill effects from these magnets. (It will be pointed out later that the lines of force are an important consideration in the physical design of a magnet for this purpose.)

Two important qualities of a magnet functioning as an implant are strength and permanence. The higher the coercive force necessary to demagnetize the magnet, the more *permanent* is the magnet. The greater the external energy available from a particular magnet (called the "peak energy product"), the more *powerful* is the magnet. (Later it will be shown how these qualities are represented on a graph; Fig. 6.) In 1949, the most powerful permanent magnetic material available was alnico V, an alloy of aluminum, nickel, cobalt, and iron. Magnetized specimens of this material were obtained for animal experiments.

ANIMAL EXPERIMENTS

Since there was no evidence of nonviable materials, certainly none with magnetic properties, being completely implanted in the jaws, animal experiments were undertaken in 1949. Dogs were made available at the Experimental Surgery Laboratory of Cornell University Medical College. These animals were involved in surgical experiments whose nature would neither interfere with nor be interfered with by the following procedures.

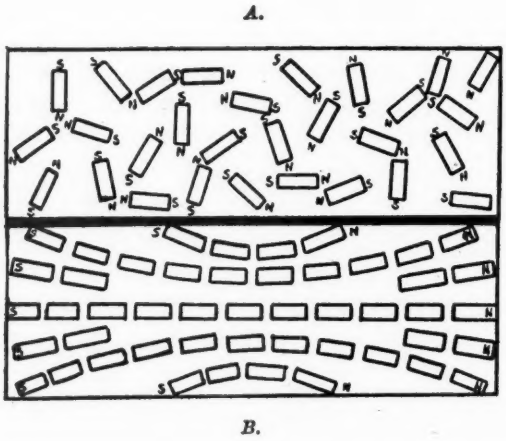


Fig. 2.—*A*, Unmagnetized substance with randomly scattered moments. *B*, Magnetized substance with parallelly aligned moments.

Because alnico V would corrode when implanted in tissue, it was necessary to coat the magnets with a relatively impervious, tissue-tolerated material. As noted, many investigators had found methyl methacrylate to be tolerated extremely well by the tissues. This was true if the acrylic resin was completely polymerized. (It had been estimated that not more than 1 in 10,000 patients would exhibit an adverse reaction to acrylic resin.[37]) Accordingly, the magnets were coated with completely polymerized methyl methacrylate by a firm which specialized in the fabrication of orbital implants, ensuring the same quality of acrylic resin as was being used successfully by ophthalmologists.

Mandibular molars were removed from the dogs and the wounds were permitted to heal for 4 to 5 weeks. Four types of materials then were implanted, two *on* bone and two *in* bone.

Subperiosteal Implants.—The materials implanted on bone were (1) cast Vitallium mesh frames, approximately 20 by 3 by 2 mm., and (2) squares of tantalum mesh, approximately 10 by 10 by 0.165 mm. The mucoperiosteum was incised sharply and retracted. The implants were placed directly on the bone and the mucoperiosteum sutured over them in an attempt to provide complete closure.

Intrabone Implants.—Those implanted in the bone were (1) alnico V magnets approximately ⅛ by ¼ by ½ inch, coated with methyl methacrylate approximately 1 mm. thick, (2) alnico V magnets approximately ¼ inch in diameter by

½ inch in length, coated with methyl methacrylate approximately 1 mm. thick, and (3) methyl methacrylate, approximately 3/16 by 3/16 by ½ inch. The mucoperiosteum was incised sharply and retracted. Cavities or "vaults" were prepared in the bone with burs and chisels. The implants were placed in the vaults and the mucoperiosteum sutured over them in an attempt to effect complete closure.

Results.—Several significant observations were made. A position of the implant above the normal height of the residual alveolar ridge prevented tension-free closure of the mucoperiosteum and precluded primary healing. This increase in height was produced by ill-fitting Vitallium subperiosteal implants and by intrabone implants which were not flush with, or below, the margins of the vault.

A too large intrabone implant provided an improper "bed" for the mucoperiosteal flap. There would be some marginal tissue slough and, of course, no primary healing. (The ½ by ¼ inch surface of an alnico V implant placed flat and flush with the residual alveolar ridge produced this reaction.)

When primary healing was not obtained, the animals were able to work the implants loose and the implants had to be removed.

When primary healing was obtained, the implants remained in place. When the animals were sacrificed, blocks of the mandible containing the implants were removed. The tissue about the implants was examined grossly and microscopically.

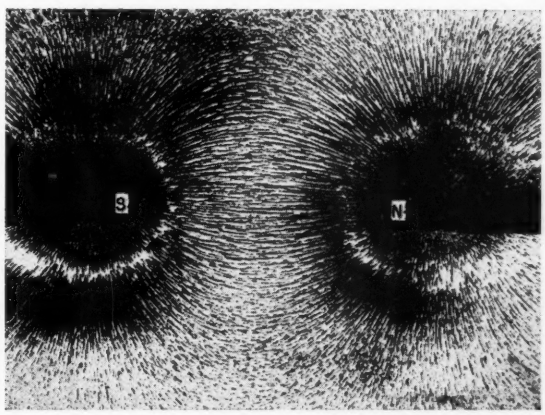


Fig. 3.—A diagram of a magnetic field of force.

There was no significant macroscopic or microscopic evidence of irritation of bone or soft tissue. Each implant appeared to be surrounded by a thin, fibrous tissue capsule; the capsule about the fibers of the tantalum mesh was demonstrable microscopically. These findings were compatible with those of other investigators.[38,39]

It was concluded from these animal experiments and from the surgical experience reported in the medical literature that a properly placed magnetic implant, if of a tissue-tolerated material, would be retained in the mandible. A clinical trial seemed to be indicated.

CLINICAL TRIAL

The first clinical trial was undertaken on a 44-year-old man in April, 1950. This patient was an elevator operator at The New York Hospital. He was in excellent health and wore a distal extension partial lower denture. The ridge was large, with a substantial amount of bone above the level of the mandibular canal. The remaining teeth were in good position and repair. It was felt that if there was any loss of residual alveolar bone, there still would be adequate bone and healthy teeth to support a partial denture. The patient, apprised of the unknown elements of this experiment, nevertheless was an anxious volunteer.

One of the rectangular alnico V magnets, covered with acrylic resin, was implanted in the posterior part of the right side of the body of the mandible. Difficulty was encountered in getting the implant flush with the margins of the vault in the bone and, subsequently, in closing the mucoperiosteum (Fig. 4). Two weeks after implantation, it was noted that a portion of the implant was exposed. Another implant was fabricated, this time of ¼ inch cylindric stock, ½ inch in length. This, too, was coated with acrylic resin. On April 30, this second magnet was implanted in the left side of the mandible. Less difficulty was encountered in placing and covering this implant. (It must be remembered that this patient had a large alveolar ridge. Magnets of these sizes could not be placed in a resorbed mandible.)

After several weeks, duplicate magnets were placed on the tissue overlying the magnets implanted in the jaw. A moderate amount of attracting force was noted between the large rectangular magnets. (At the area of exposure of the implant on the right, these magnets were in direct contact, except for the acrylic resin covering the implant magnet.) A substantially lesser amount of attraction was noted between the cylindric magnets. It was concluded that alnico V magnets small enough to be implanted in edentulous mandibles with resorbed ridges would be too small to provide adequate magnetic force to aid denture retention and that alnico V magnets strong enough to aid denture retention would be too large to be implanted in resorbed mandibles.

The magnets were removed from the patient's jaw on May 26, 1950. Gauze dressings were placed in the wounds. Granulation proceeded at a rapid rate, and Fig. 5 shows the complete bone regeneration. Clinical trials were discontinued in the hope that they would be resumed when and if a more powerful magnetic material was developed.

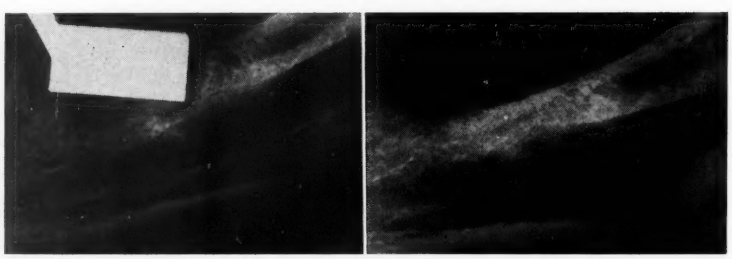


Fig. 4. Fig. 5.

Fig. 4.—The first Alnico V magnetic implant. (A hemostat is holding the film.)
Fig. 5.—Bone regeneration after the removal of the Alnico V implant.

PLATINUM-COBALT MAGNETS

In December of 1951 it was learned that a very powerful magnetic alloy of platinum and cobalt could be obtained. This material had a peak energy product (BH max. millions) of approximately 9 as compared to 4.5 for alnico V (as indicated by the arrows in Fig. 6). In addition to this obvious potential of greater peak energy product, the platinum-cobalt alloy had several other very significant

advantages: (1) a better length/diameter ratio, (2) a greater efficiency over a varying air gap, (3) substantial isotropy magnetically, (4) greater magnetic stability, and (5) tissue toleration (shown by later animal experiments).

Several disadvantages to the platinum-cobalt material became evident immediately: (1) comparatively high cost, (2) limited availability, and (3) extreme difficulty in fabrication.

Length/Diameter Ratio.—The peak energy product is obtainable only if a magnetic material is used in its precise length/diameter ratio. The length/diameter ratio is different for each magnetic substance and is intrinsic to that substance. Deviations from the optimum length/diameter ratio result in a decrease in the available energy product. A magnet to be implanted in the jaw often cannot conform to the optimum length/diameter ratio because its design is influenced by the anatomy of the bone. For example, the optimum length/diameter ratio of alnico V is 5. A magnet measuring 5/8 by 1/8 inch would provide the peak energy product but is too long to accommodate for the anteroposterior and superoinferior curvatures of the body of the mandible. The shorter magnet which must be used does not realize all of the potential energy of the material.

With an optimum length/diameter ratio of 0.7, the ideal length of a platinum-cobalt implant of 1/8 inch diameter would be 0.0875 inch. Implants this size are too small to provide adequate retentive force and are difficult to handle. After substantial experimentation, it was determined that an implant 1/4 inch long and 1/8 inch in diameter would be the optimum size. This size of magnet could be implanted in almost any mandible and would provide ample retentive force.

It must be noted that any increase in length beyond this optimum size makes the implant much more difficult to place and may endanger the physiologic condition of the adjacent tissue. Even if implanted successfully, a longer magnet does not provide significantly more energy because of the pronounced deviation from the optimum length/diameter ratio of platinum-cobalt. More of its potential energy is realized from a platinum-cobalt magnet 1/8 inch in diameter by 1/4 inch in length than from one of any greater length.

Efficiency Over a Varying Air Gap.—All magnetic materials are most efficient when operating across a fixed air gap, that is, when the distance between the magnet and the material it is attracting is fixed and static. When the intervening distance, or air gap, varies, the magnet operates at a lower level of efficiency. Some materials lose a substantial amount of force when operating across a varying air gap; others are fairly effective under these circumstances. The distance between the magnet in the mandible and the magnet in the denture varies, not only from patient to patient, but within the same mouth under different circumstances. The gap between the two magnets at rest would diminish when the overlying tissue was compressed under the stresses of mastication. The air gap would increase if the denture shifted slightly or was dislodged momentarily.

Fig. 6 is a graph on which peak energy product curves and the demagnetization curves of platinum-cobalt and alnico V are plotted. Superimposed are two lines, one representing the operating line for a fixed air gap, the other the operating line for a varying air gap. The vertical figures on the right represent the residual magnetic induction in a material. Significance is attached to the percentage

loss, expressed in these figures, between the fixed and varying air gap application. The brackets on the right indicate a loss of 80 per cent for alnico V (from 10 to 2) but a loss of only approximately 20 per cent for platinum-cobalt. This indicates that platinum-cobalt is a much more efficient material in the implant application.

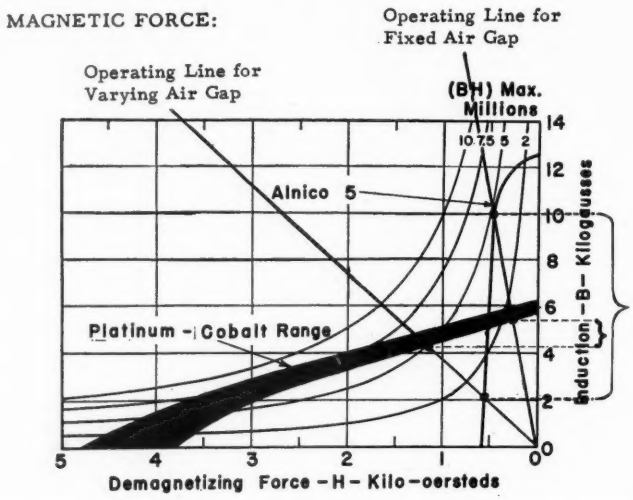


Fig. 6.—Graph of peak energy product curves of Alnico V and early platinum-cobalt alloy magnets.

Isotropic Quality Magnetically.—A magnetic material is termed anisotropic if it has preferred orientation so that the magnetic characteristics are better along one axis than along any other axis. A magnetic material is termed isotropic if it has the same magnetic characteristics along any axis of orientation. In other words, an anisotropic material is strongest when magnetized in one direction; isotropic material may be magnetized in any direction equally as well. Alnico V is anisotropic; platinum-cobalt is isotropic. As will be seen, this isotropic quality assumed importance when it was decided to change the direction of magnetization of the implants 90 degrees— from "end to end" to "through the diameter."

Magnetic Stability.—Reference was made earlier to the restraining forces which maintain the magnetic domains of permanent magnets in alignment. There are a number of factors which tend to weaken these restraining forces and thus cause demagnetization. The most common factors encountered are external magnetic fields, temperature change, and mechanical shock.[40] Reference to the base line of Fig. 6 shows that, while a force of approximately 580 oersteds will demagnetize alnico V, a force of 4,500 oersteds is needed to demagnetize platinum-cobalt. Substantially large external magnetic fields would have to be encountered for a platinum-cobalt implant to be demagnetized.

Platinum-cobalt maintains its structural stability up to 500° C. and is very resistant to changes caused by mechanical shock. In fact, this material is so stable when compared to the other magnets that it is referred to as a "lifetime" magnet

rather than a "permanent" magnet. Because, when used as an implant, only lethal high voltage and temperatures above 500° C. will demagnetize this material, it should be expected to function at full efficiency for the lifetime of the patient.

All indications were that the platinum-cobalt alloy would be substantially stronger than alnico V. Several specimens were obtained which measured ⅛ inch in diameter and ¼ inch in length, one-fourth of the size of the alnico V which had been implanted. Each ¼ by ⅛ inch magnet could lift 20 to 40 Gm. of iron. The material was coated with methyl methacrylate and a clinical trial was planned.

TANTALUM MESH OVERLAY

Consideration was given at this time to the possibility that a small magnet implanted in the mandible might be pulled through the covering mucoperiosteum by the force of attraction of the overlying magnet in the denture. It was felt that this could be prevented if the covering mucoperiosteum were reinforced with a section of tantalum mesh. This would be done in the same manner that general surgeons use this mesh to reinforce the abdominal wall in the repair of ventral hernias.[41] Accordingly, some thin, flexible, and tissue-tolerated tantalum mesh was obtained to be used as shown in Fig. 7. In this diagram, the implant magnet is placed in the prepared "vault" in the mandible, flush with the bony margins. The tantalum mesh overlies the implant and extends over several millimeters of bone at the margins. It is flexible and easily burnished to conform to the contour of the mandible. The mucoperiosteum is closed over the tantalum, completely covering it and the implant. It was felt that, employed in this fashion, the tantalum mesh would prevent

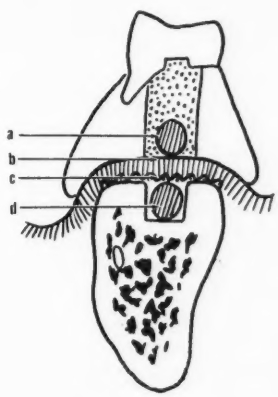


Fig. 7.—*(a)* **The denture magnet in the denture;** *(b)* **covering mucoperiosteum;** *(c)* **tantalum mesh resting on mandibular bone;** *(d)* **implant magnet in the "vault" in the mandible.**

the denture magnet from "pulling" the implant out of the tissue. (The use of the tantalum mesh for this purpose proved unnecessary. The implants are so well tolerated that bone grows about their margins and maintains them firmly in position. The mesh, however, is still part of the implant, but for different reasons.)

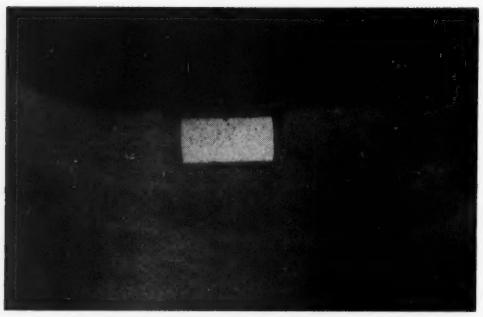


Fig. 8.—Roentgenogram of the first Behrman Magnetic Implant at time of implantation (April, 1952).

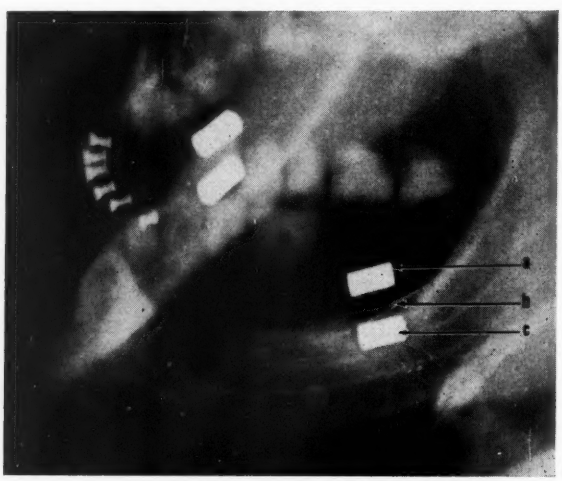


Fig. 9.—A lateral jaw roentgenogram 8 months after insertion of the first Behrman Magnetic Implant: *(a)* the denture magnet in the denture; *(b)* tantalum mesh; *(c)* the implant magnet in the mandible (see Fig. 20).

PLATINUM-COBALT CLINICAL TRIAL

The 53-year-old technician in charge of the animals at the surgical research laboratory had been an unsuccessful wearer of a complete lower denture. Observing and assisting at the animal experiments, he requested that he be an early trial patient (case 1).

In April, 1952, an acrylic-coated ¼ inch long by ⅛ inch diameter platinum-cobalt magnet (see Fig. 12, *A*) was placed in the right side of the mandible (Fig. 8). (Today's surgical technique is described later.) One week later an implant was placed in the left side of the mandible. One month after implantation, full upper and lower dentures were constructed.* These dentures were worn for several weeks. The denture magnets then were placed in the denture in essentially the manner to be described under the section on denture construction methods.

An 8 month period of observation ensued. There were no gross deleterious changes in the mucosa overlying the implant. Roentgenographically, bone appeared to fill in any areas of surgical defect. The question, "Could magnetic materials be implanted safely into the jaw?" was answered affirmatively enough to warrant additional clinical trials (Fig. 9).

*The dentures were constructed by George F. Egan, D.M.D., Attending Oral Surgeon-in-charge, The New York Hospital, and Associate Professor of Clinical Surgery (Dental), Cornell University Medical College.

WOULD THE FORCE OBTAINED BE ADEQUATE TO AID IN DENTURE RETENTION?

In this first trial of platinum-cobalt implants there was a remarkable improvement in lower denture retention as soon as the denture magnets were placed. Several months later, in the thought that the excellent retention might result from the patient's ability to control the lower denture, the magnets were removed from the denture. The defects in the base were filled with soft wax and the dentures were placed in the mouth. Retention was minimal. As soon as the magnets were replaced in the dentures, the retention was excellent. This procedure has been repeated many, many times to demonstrate the effect of the magnets. This supplied an affirmative answer to the question, "Would the force be adequate to aid in denture retention?"

During the ensuing years, additional clinical trials continued to supply affirmative answers to these questions. Clinical, roentgenologic, and microscopic observations led to improvements in the implant. Further animal experiments, too, were rewarding.

IMPROVEMENT OF THE IMPLANT

Change of the Coating.—A critical characteristic of magnetic force is expressed in Coulomb's Law $\left(f = \frac{i}{u} \cdot \frac{m_1 m_2}{r^2} \right)$, which states that "magnetic force is inversely proportional to the *square* of the distance between the poles." Because of the desire to get as much magnetic flux from as small an implant as possible, it is essential to keep the distance between the magnet in the jaw and the magnet in the denture at a minimum. With the loss of magnetic force being proportional to the *square* of the distance between the two magnets, any unnecessary space, no matter how trivial, could mean the loss of considerable force.

In that we did not know whether or not the platinum-cobalt alloy was tissue tolerated and were too impatient to await the result of animal studies, it was decided to coat the magnets with methyl methacrylate as had been done for the Alnico V implants. This acrylic resin coating, which had to be intact and completely polymerized, was relatively thick despite every effort to make it as thin as possible. This thickness, of course, increased the distince between the magnets in the jaw and those in the denture, diminishing their effectiveness. Effort was made to obtain a thinner coating material.

In 1949, LaVeen and Barberio[42] reported the exceptionally high tissue toleration of a new plastic, polytetrafluoroethylene. This chemically inert material could not be wet with water and could not be cemented to any known substance. Their investigation showed polytetrafluoroethylene to be so well tolerated by the tissues that nylon and methyl methacrylate were comparatively "potent excitors of tissue reaction." Of additional interest was the fact that this material could be applied to metals to provide extremely thin, impervious coatings.

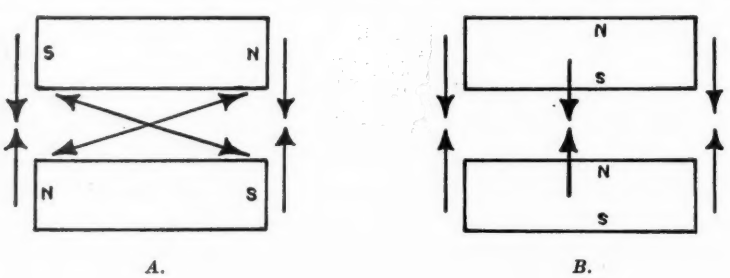
In November, 1952, two magnets were coated with polytetrafluoroethylene. An aqueous dispersion was sprayed on and then fused at 700° F. (365° C.). This was repeated seven times. The resultant film measured 0.006 inch, about

the thickness of a page in this journal. This new coating on the magnet, substantially thinner than methyl methacrylate, required less space between the implant magnet and denture magnet, allowing for greater attraction between the two. This coating since has been reduced to 0.003 inch.

Change in Direction of Magnetization.—It was demonstrated that changing the direction of magnetization of the magnets would increase the amount of available energy. (The shorter the lines of force are, the stronger they are; conversely, the longer they are, the weaker they are.) The magnets had been magnetized from end to end, in the customary fashion, so that the north pole was at one end and the south pole at the opposite end. With the denture magnet placed over the implant magnet, a number of the lines of force between the magnets were repellent (Fig. 10, *A*). The greatest amount of attractive force was available only if the magnets were lined up precisely. Any irregularity of the overlying mucosa or slight shift of the denture could cause lengthening of the attracting lines and shortening of the repelling lines, with a measurable amount of loss of attraction. With the magnets magnetized through the diameter, so that the entire top surface is one pole and bottom surface the opposite pole, *all* the lines of force between the magnets are *attracting* (Fig. 10, *B*). The magnets now can be skewed with very little loss of energy.

Changes in Magnet Design.—To accompany the change in direction of magnetization a change in design was made. By flattening the magnets, more of the lines of force between the two magnets were shortened and greater energy was made available. As shown in Fig. 11, *A,* with a cross section of cylindric magnets, the central line of force is the shortest; those at the periphery are longer and, consequently, weaker. With a cross section of flattened magnets (Fig. 11, *B*), more of the lines of force are short and, consequently, stronger. The shape of the magnet now is that of a flattened cylinder, ¼ inch in length, less than ⅛ inch in height, and a little more than ⅛ inch in width. To be precise, it measures 0.25 by 0.14 by 0.10 inch (6.35 by 3.55 by 2.54 mm.) (Fig. 12, *B*).

Changes in the Mesh Overlay.—The second time the new flattened magnets, magnetized through the diameter, were used, an interesting phenomenon occurred (Table I, case 3). The magnet was so strong that it was attracted to the needle used to suture the mucoperiosteum. It followed the direction of the

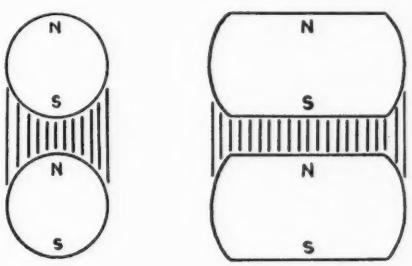


A. *B.*

Fig. 10.—*A*, Repelling lines of force (long lines) between like poles of magnets magnetized end to end. *B*, Only short attracting lines of force exist between magnets magnetized through their diameters.

needle passing through the tissue and literally "turned over on its side" in the vault. This meant that the magnetic field of attraction was not in an inferosuperior direction in the mandible, but rather in a lateromedial or buccolingual direction. This, of course, was of little value for denture retention, and the implant had to be reset. (The replacement was postponed successfully for 13 months, permitting histopathologic evaluation of the overlying soft tissue at the time of removal; see Fig. 21.) To prevent this rotation of the implant in the vault in the bone, it was necessary to fasten the tantalum mesh to the magnet. The mesh, overlying the bony margins of the vault, would be fixed in position and would prevent the implant from turning. The only practical method of attaching the mesh to the magnet was by means of the polytetrafluoroethylene coating. Initially, the entire mesh was coated with plastic (Fig. 13, *B*). Subsequent studies by Georgiade* at Duke University indicated that an uncoated tantalum mesh would be more desirable. Polytetrafluoroethylene is so well tolerated by the tissues that it affords no stimulus to granulation. If a portion of the mesh is not covered by primary healing of the mucoperiosteum, epithelization may not occur. The raw or uncoated tantalum, on the other hand, appears to encourage epithelization.

The implant today has the magnet coated completely with polytetrafluoroethylene. Attached to one flat surface, by being incorporated in this coating, is a 0.5 by 0.5 inch (12.7 by 12.7 mm.) rectangle of tantalum mesh 0.0065 inch (0.165 mm.) thick. All of the mesh, other than its area of attachment to the magnet, is left uncoated (Fig. 13, *C* and *D*).



A. *B.*

Fig. 11.—*A*, Few short lines of force act between cylindric magnets. *B*, More short lines of force act between flattened magnets.

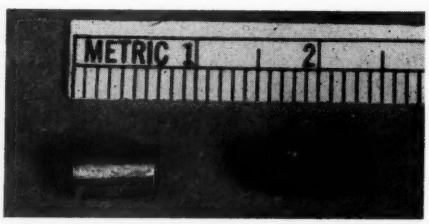
It has been mentioned that bone grows about the margins of the implants, which maintains them firmly in position. As a result, there is no need for the tantalum mesh to provide "reinforcement" of the overlying mucoperiosteum. The mesh, therefore, is attached to the magnet primarily to prevent it from rotating in the vault in the bone and, secondarily, to suspend it in position at a level with the bony margins if the vault is prepared too deeply.

*N. G. Georgiade, Professor of Plastic, Maxillofacial, and Oral Surgery, Duke University, School of Medicine, Durham, N. C.: Personal communication.

Changes in Heat Treatment, Magnetization Method, and the Platinum-Cobalt Alloy.—The alloying of platinum and cobalt was developed in Germany. The heat-treating process, which is responsible in large measure for the remarkable magnetic properties, was developed in the United States. This intricate and detailed process is costly and time consuming. An error in either heat treatment or alloying apparently was responsible for a defective batch of magnets obtained in 1954. These were defective in that their magnetic flux was relatively negligible. Unwittingly, these magnets were used in a clinical trial (Table I, case 8).

Because of their high cost, platinum-cobalt magnets had no practical application other than as these implants. Consequently, in 1954, the patentee lost interest and discontinued experimental production. After a protracted period of time, sufficient interest was aroused in an engineering concern to warrant production of these magnets. This was a firm with long experience with sintered metals, rich in research and engineering skills, and of high ethical standing. It was understood that there was to be no commercial exploitation of this work.

The new engineering skills, along with new and more efficient equipment, produced pronounced changes in heat treatment, in magnetization methods, and in



A. *B.*

Fig. 12.—*A*, An early cylindric methyl methacrylate–coated magnet (case 1). *B*, A polytetrafluoroethylene-coated flattened magnet (cases 2, 3, and 4).

the formulation of the alloy itself. These improvements had two significant results: (1) there was a sixfold increase in magnetic flux without any increase in the dimensions of the magnet and (2) animal studies showed this *new* alloy to be tissue tolerated.

ADDITIONAL ANIMAL EXPERIMENTS

Additional animal experiments were undertaken to determine the tissue tolerability of the new platinum-cobalt alloy. Once again dogs were made available at the Experimental Surgery Laboratory of Cornell University Medical College. This time buccal mucoperiosteal flaps were reflected from the mandibles of the dogs. Adjacent bur holes were drilled in the bone so that they "kissed" or touched tangentially. Two platinum-cobalt magnets were positioned, one in each hole. One magnet was coated with polytetrafluoroethylene and the other was left uncoated. The flaps were replaced and sutured. After 10 weeks the implants were removed. Histopathologic examination showed excellent tissue toleration of both

the uncoated and coated implants. In fact, it was impossible to tell which tissue approximated the raw metal and which approximated the plastic coating (Fig. 14). The sections also demonstrated that there was no adverse reaction whatsoever of the tissue between the magnets—that tissue through which the magnetism "passed."

It seems apparent that this particular platinum-cobalt alloy is tissue tolerated and that there is no need to coat the implant with plastic for that purpose. However, the coating of polytetrafluoroethylene appears to be the most feasible method of attaching the tantalum mesh to the magnet.

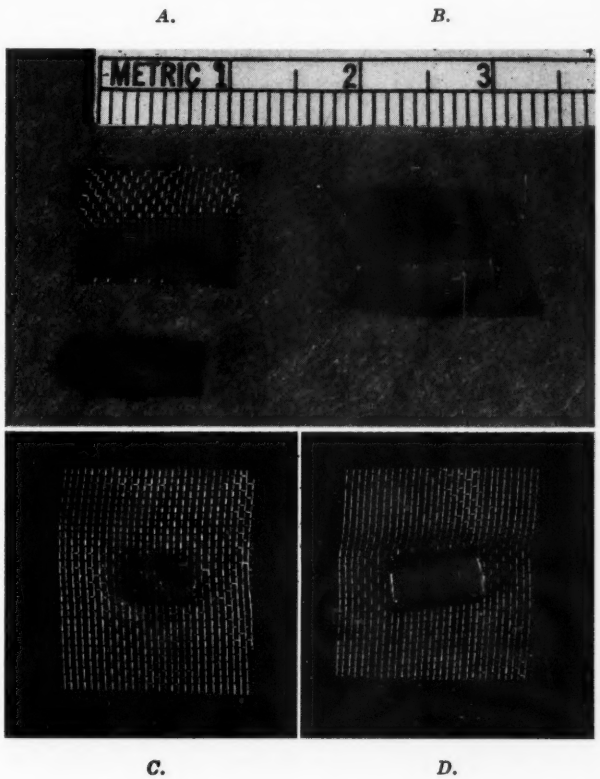


Fig. 13.—*A*, Separate magnet and tantalum mesh (cases 2, 3, and 4). *B*, Attached magnet and mesh both coated with polytetrafluoroethylene. *C* and *D*, Polytetrafluoroethylene-coated magnet attached to raw tantalum (*C*, top view; *D*, bottom view).

It must be emphasized that a slight change in formulation of an alloy may impart substantially different characteristics. For example, cobalt, chrome, and steel are all tissue toxic. Only in a precise proportion do they alloy to form Vitallium, a highly tissue-tolerated material. Similarly, the platinum-cobalt magnets used in these tests were of a specific formulation. The observed tissue tolerability applies to that specific alloy—it may or may not apply to alloys of other percentages of these same two metals. Implications should not be drawn from these experiments and applied to other formulations.

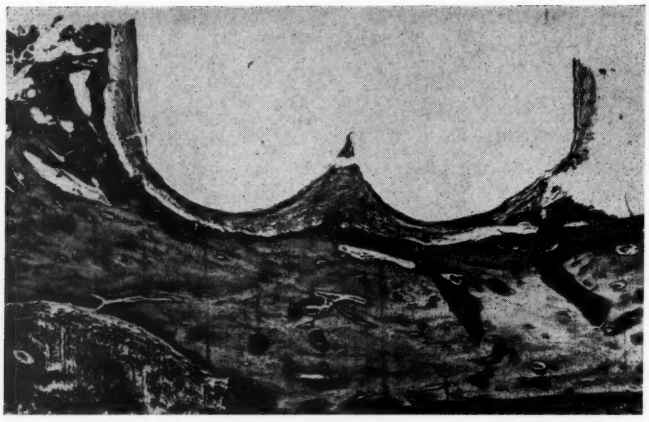


Fig. 14.—A microscopic section from the mandible of a dog, indicating the tissue toleration of the new alloy. The tissue showed the same reaction to coated (polytetrafluoroethylene) and uncoated magnets.

Could a Simple, Safe, and Inexpensive Surgical Technique Be Evolved?

EVALUATION OF THE PATIENT

The importance of good surgical and good prosthetic technique will be emphasized; the selection of patients is perhaps equally as important. The implantation of magnets in the jaw is an aid to *retention*. For example, it is not indicated for the patient with good ridges who complains of "soreness" when no areas of irritation can be found. It may or may not be indicated for the patient with good ridges who psychologically is unable to wear dentures. It is not a panacea. But it can be of enormous value, both physically and psychologically, to the patient with a retention problem resulting from anatomic difficulties.

It is doubtful whether anyone can predict with certainty that a patient will be an unsuccessful denture wearer. For that reason, no implant should be placed until the patient has had an opportunity to try a conventional complete lower denture. Then, of course, if the implants are used, the improvement will be appreciated even more because the patient will be able to make a comparison. This should answer the question of whether the implants can be placed in extraction wounds. Aside from the fact that this is unsound surgically and mechanically (because of tilting of the implant during healing), a conventional complete lower denture should be given a trial first.

The implantation of each magnetic implant takes approximately 20 minutes. It may be considered less traumatic than the "open" or "surgical" removal of a molar. In general, a patient able to undergo the latter procedure can have a magnetic implant placed. The patient's physician and dentist are the best judges of the suitability of the patient. Rheumatoid disease, inflammatory retinopathy, and other conditions where foci of infection may be critical can be considered as contra-

indications. A thorough clinical and roentgenographic examination (including lateral jaw projections) of the mouth and jaws are performed to rule out any pathosis of the soft or hard tissues. The roentgenograms also will provide an indication of the approximate position of the mandibular canal. Because the majority of the candidates for this procedure are of advanced age, recommendations for antimicrobials, premedication, anesthesia, and analgesics should be discussed with the patient's physician.

ANATOMY

The fourth principle of implantation is that "the implant must not interfere with the physiologic condition of the adjacent tissue." The mandible is the densest bone in the body with the exception of the neck of the femur. Each side is nourished by a single artery entering the medial aspect of the ramus. Any implant placed in the bone should be as small as possible so as not to interfere with the blood supply to that area. It has been pointed out that the size of magnetic implant that would be the most efficient was determined on the bases of the physiologic condition of the bone and the physical properties of the magnetic material. Any larger implant may compromise the nutrition of the contiguous tissues.

Consideration must be given to the mandibular neurovascular bundle in its course through the mandible from the lingula to the mental foramen. Many dry specimens of mandibles were either dissected or roentgenographed with a pipe cleaner in the mandibular canal. These studies indicated that, in the first or second molar region, the mandibular canal most frequently was buccal to the midline of the denture-bearing surface (Fig. 15). The lingual flare of the mylohyoid ridge appears responsible for this apparent relationship. Clinical experience has borne out these observations. It always has been possible to find adequate space lingual to the mandibular canal in which to place the magnetic implant.

ANESTHESIA

The anesthesia of choice is local, mandibular block anesthesia, either unilateral or bilateral, depending on whether one or both implants are being placed at a time. The procedure is atraumatic, of relatively short duration, and performed on anxious, willing, and usually aged patients. The work is precise and detailed and might be hampered by the presence of a mouthprop and throat pack. Two sessions of ambulatory general anesthesia each of 20 minutes' duration or one of 40 minutes may not be judicious for the patients in this age group. It is suggested that the patient requiring general anesthesia for this procedure be hospitalized and a closed (endotracheal) system be employed.

ANTIMICROBIALS

Although routine prophylactic use of antibiotics is to be condemned vigorously,[43] this procedure has been considered an exception and should be at least until the evidence shows that it can be performed successfully without antimicrobials. Administration is begun 1 day prior to the operation and continued for

1 week. Penicillin, which was used at first, has been supplanted by the tetracyclines. The latter may have to be replaced in time, depending upon the resistive properties of the changing bacterial population.[43] The choice of antimicrobial should be based on the patient's tolerance and the local prevalence of resistant organisms. Six implants have since been placed successfully without antibiotics.

PREMEDICATION

All patients should be premedicated for sedation and for elevation of the pain threshold. Combinations of short-acting barbiturates (sodium pentobarbital or secobarbital) and analgesics (aspirin or meperidine) are most useful. At least 30 minutes should transpire after oral administration of premedicants before creating a nerve block. It is mandatory that these patients be accompanied when they leave the office. The administration of vitamin C, 500 mg. daily, may be started 2 to 3 weeks preoperatively.

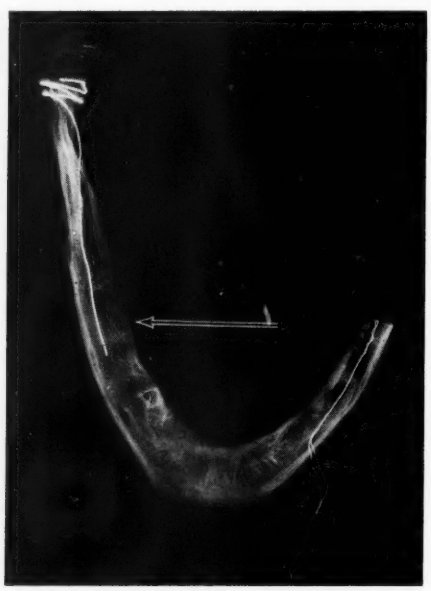


Fig. 15.—A roentgenogram of a dried mandible with a wire in the mandibular canal. Sufficient bone exists lingual (medial) to the mandibular canal for an implant.

ARMAMENTARIUM

The following equipment and materials are suggested to facilitate the surgical procedure: (1) No. 15 blade (Bard Parker) scalpel, (2) sharp, pointed periosteal elevator, (3) sutures—00 white silk or cotton for retraction; 000 black silk for closure, (4) No. 4 Lane cleft palate needles, half round, (5) needle holder, (6) two hemostat clamps, (7) scissors, (8) rongeur, (9) bone file, (10) handpiece and contra-angle with (11) a water spray attachment connected to a bottle of warm sterile saline or (12) a water (bulb) syringe and warm sterile saline, (13) burs—round Nos. 6, 8, and 10, fissure, end cutting, (14) periodontal probe, (15) small

spoon excavator, (16) cotton pliers, (17) orangewood stick, (18) beaver-tail burnisher, (19) copper or brass suction tip, (20) 2 by 2 sponges, (21) sterile rubber gloves, and (22) benzalkonium chloride (Zephiran).

SURGICAL TECHNIQUE

In essence, the surgical technique consists of preparing a class I occlusal cavity or "vault" in the bone. It will measure ¼ inch in length, a little more than ⅛ inch in width, and less than ⅛ inch in depth. Both implants may be placed at the same session or it may be more judicious to do the second side a week later. A meticulous sterile technique should be observed. The implants are obtained in a set of four—two implant magnets and two denture magnets.* They are packed individually in benzalkonium chloride in small glass jars. They should be handled only with sterile instruments, and if contaminated, they should be resterilized by soaking for at least 18 hours.

Using a No. 15 blade, the mucoperiosteum is incised sharply, along what would be the crest of the ridge were it not resorbed, from the third molar area to the bicuspid area. The mucoperiosteum is reflected carefully for several millimeters on either side of the incision (Fig. 16, *A*).

Retracting sutures are placed through the mucosa *and underlying periosteum.* About four retracting sutures are placed along the margin of each flap. A hemostat is used to clamp the free ends of the sutures. The flaps then are reflected more widely and retracted (Fig. 16, *B*).

The widest, flattest area of bone is selected as the implant site. Any fine projections or protuberances are removed and the area is filed smooth.

With a No. 6 round bur, three holes about 1 mm. apart are drilled in a straight line in an anteroposterior direction. The holes are drilled only to the level of the diameter of the head of the bur. Warm sterile saline solution is played over the field continuously while the bur is in motion (Fig. 16, *C*).

A periodontal probe is placed in each bur hole successively to palpate for the mandibular neurovascular bundle (Fig. 16, *D*). If it is encountered, additional holes are drilled away from the canal either medially, laterally, anteriorly, or posteriorly.

Using a No. 8 bur, the three selected holes are enlarged; the bur is sunk only to the level of the diameter of its head.

Again the neurovascular bundle is probed for, and the holes are relocated if necessary.

Using a No. 10 round bur, the three selected holes are enlarged; only the head of the bur is sunk. If properly placed, the three holes now will be connected. The No. 10 bur is approximately the width and depth of the implant. It now should be necessary only to square up the cavity preparation with fissure burs (Fig. 16, *E*).

The denture magnet, which is the same size as the implant magnet, is used as a guide. It is placed in the vault in the bone. The superior surface should

*Identified as the Behrman Magnetic Implant; obtainable only from Ethical Specialties, Inc., Paterson, N. J.

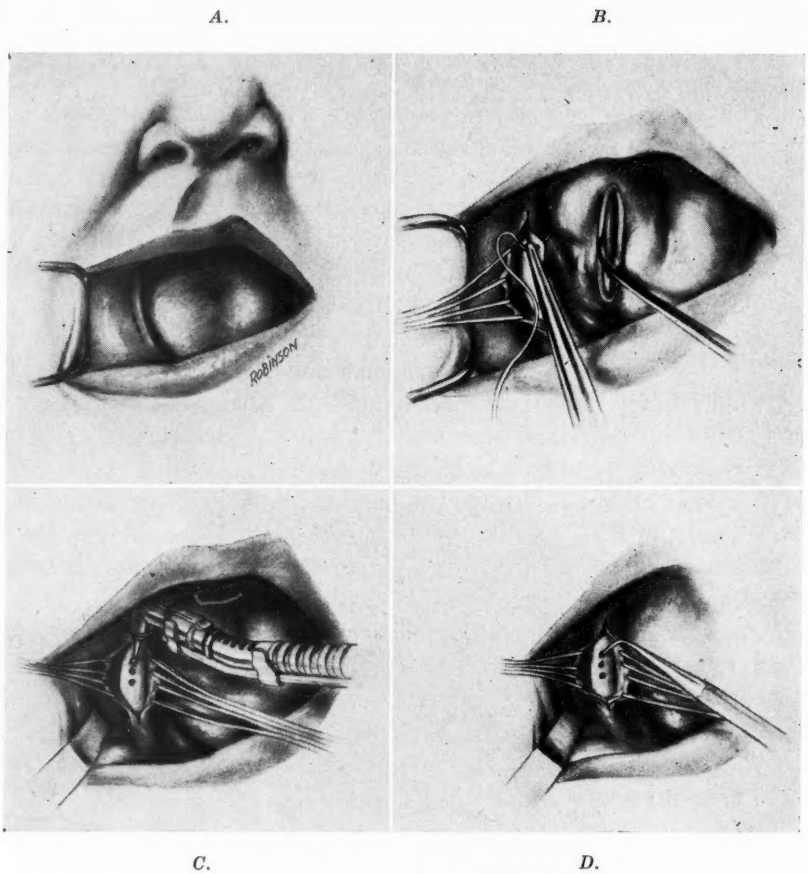


Fig. 16, *A* to *D*.—Surgical technique. *A*, The incision. *B*, Retracting sutures. *C*, Bur holes through cortical bone. *D*, Probing for neurovascular bundle.

be flush with the level of the bone. The vault should be deepened, lengthened, or widened where necessary until the denture magnet fits properly. Because the magnets are attracted to steel instruments, it is necessary to use an orangewood stick to position the magnet (Fig. 16, *F* and *G*).

When the vault has acquired its proper dimensions, it is debrided with the spoon excavator and by flushing with warm saline.

The implant is placed in the vault. Its position is checked carefully, using the orangewood stick for instrumentation. The vault is adjusted where necessary.

The attached tantalum mesh is burnished over the bone. Any excess or interferences are trimmed with scissors; none of the wire ends should project upward or outward (Fig. 16, *H*).

Using the retracting sutures as a guide, the mucosa *and periosteum* are sutured closed over the implant (Fig. 16, *I*). Pressure against the implant is made repeatedly with the orangewood stick to be sure it is retained in the vault.

The procedure is repeated for the opposite side if both are being done at the same session.

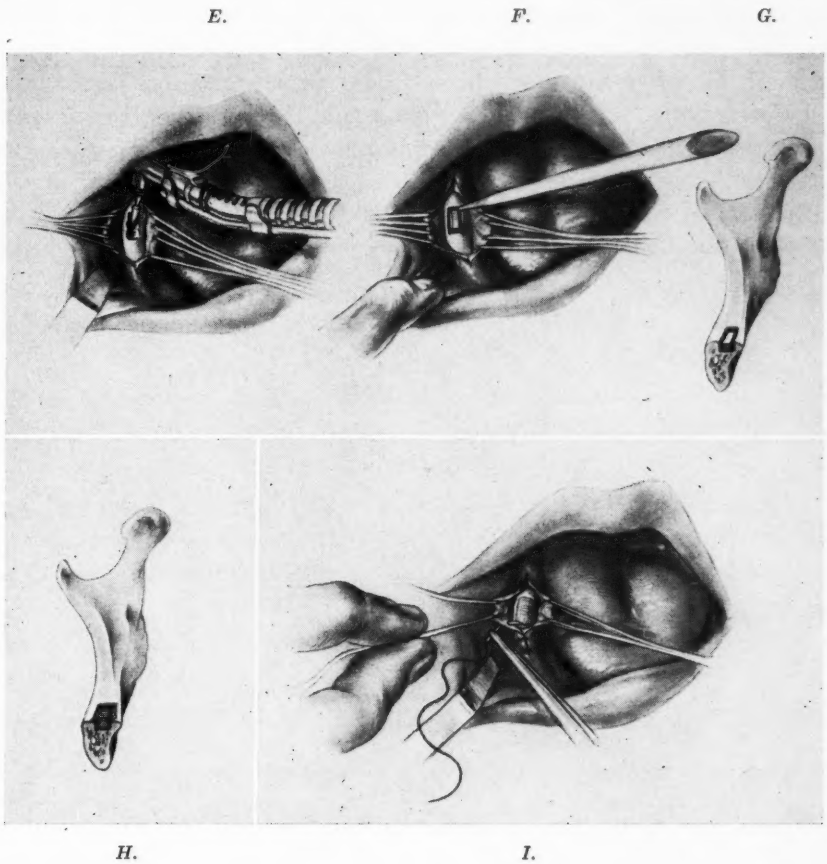


Fig. 16, *E* to *I*.—Squaring the "vault." *F*, The denture magnet acts as a guide (note the orangewood stick). *G*, Cross section showing the top of the magnet flush with the bone. *H*, The implant magnet in the vault. *I*, Suturing.

Postoperative roentgenograms are made to be certain that the implant is in the vault.

The patient's old lower denture, slightly relieved if necessary, is worn as a splint.

COMMENTS ON THE SURGICAL TECHNIQUE

The Incision.—Because there is contraction during healing of every incision, it is suggested that the incision *not* be made in the region of the mucobuccal or mucolingual fold. Contraction here will diminish the already minimal denture-supporting area. If the mucosa *and* periosteum are sutured carefully, there should be no problem with primary healing.

Retracting Sutures.—The use of retracting sutures, although time consuming, is one of the most important steps of the surgical technique. It was learned by experience that the mucosa and periosteum have a tendency to separate in the operative area, with the periosteum contracting markedly. Unless the two layers

are kept together with retracting sutures, only the mucosa may be available for closure, and some sutures are likely to slough out. This leaves an exposed area which must fill by granulation. In addition, metal retractors are a nuisance because the magnets "jump" out of the vault onto the retractors. Plastic retractors are bulky and cumbersome. More important, however, is the fact that injudicious retraction with metal instruments may traumatize the mental nerve and result in hypesthesia of the lip (Table I, case 8). Retracting sutures are atraumatic and gentle to the tissue; their use minimizes postoperative edema and discomfort.

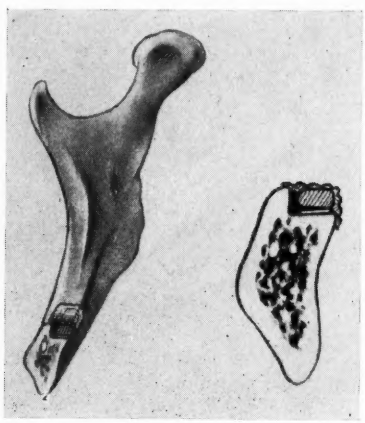


Fig. 17.—If there is no lingual wall to vault in the mandible, the tantalum mesh is used to form a wall.

Probing for the Neurovascular Bundle.—This is an essential step in the procedure. Usually the mandibular canal will not be encountered. Implants have been placed without difficulty in mandibles no thicker than a lead pencil. In these severely resorbed mandibles, it may be necessary to make a vault in the mylohyoid "shelf" or "flare" that is without a medial bony wall. The tantalum mesh may be placed along the medial (lingual) surface of the bone and the implant will provide its own "wall" (Fig. 17). There is no contraindication to laying bare the medial or lateral aspect of the neurovascular bundle and approximating it with the implant.

Burnishing the Tantalum Mesh.—Usually the tantalum mesh may be trimmed so that a few millimeters overlie the bony margins of the vault. This will "suspend" the implant in proper position and keep it from turning during suturing. Sometimes, it may be desirable to utilize more of the mesh, burnishing it against the bone. The wire ends of the mesh may feel rough and sharp. This material is tolerated very well by the tissues and will cause no difficulty as long as the ends do not project far upward or outward into the tissue.

Maintaining the Implant in Position During Suturing.—The magnets are very strong and have a tendency to "jump" towards steel instruments. During suturing, the implant beneath the mucoperiosteum may become attracted to the

needle holder or scissors and move out of the vault. Its "seat" or position should be checked frequently with an orangewood stick during the surgical operation and then with an immediate postoperative roentgenogram. Above all, do not place a denture magnet in the mouth to demonstrate how it is attracted to the implant; removing the denture magnet will pull the implant out of the vault (Table I, case 10). Caution the patient not to experiment at home to see if paper clips, a nail file, etc., are attracted to the implant.

Use of an Air Turbine.—The technique may be adapted with ease to high-speed air turbine engines. The vault is outlined and shaped with a fissure bur. Occasional probing for the neurovascular bundle is advisable.

POSTOPERATIVE CARE

Because all patients undergoing this procedure are "complete denture failures," they have at least one lower denture. This should be worn postoperatively for the first 24 to 48 hours to make certain that the implant remains in the vault. The denture may be worn longer and the patient can maintain his normal routine, as long as there is no undue pressure on the operative site.

Ice packs should be used for the first 24 to 48 hours (½ hour on, ½ hour off, alternately). If there is any postoperative edema after 48 hours, a heating pad or hot water bottle may be used in the same fashion.

After 24 hours, warm saline rinses should be used upon arising, after meals, and upon retiring.

A liquid diet should be prescribed, with progression to soft foods as tolerated. Adequate fluid intake must be maintained.

Analgesics should be prescribed. Codeine sulfate, 0.032 Gm., or meperidine (Demerol), 50 mg., one or two tablets every 4 hours, is suggested if a supplement to aspirin or APC tablets is required.

Antimicrobials are continued for 1 week, and vitamin C is continued for 1 month.

Could Current Denture Construction Methods* Be Employed

SUGGESTED CHANGE IN CONSTRUCTION

This implant method utilizes the conventional lower denture. Whatever impression and construction methods and materials the dentist has found best for complete dentures should be employed. Any impression technique, a plastic base or a metal base, porcelain teeth or plastic teeth, inclined cusps or zero degree cusp teeth may be used. (Egan used a mucostatic impression technique and plastic teeth and bases.) The only change is that the posterior buccal flanges should be made of clear acrylic resin. (It will be found, also, that the greater resistance to displacement of dentures with this method may permit some overextension of the borders.)

*The prosthetic technique was developed by George F. Egan, D.M.D., who constructed all of the dentures used during the first several years of the study.

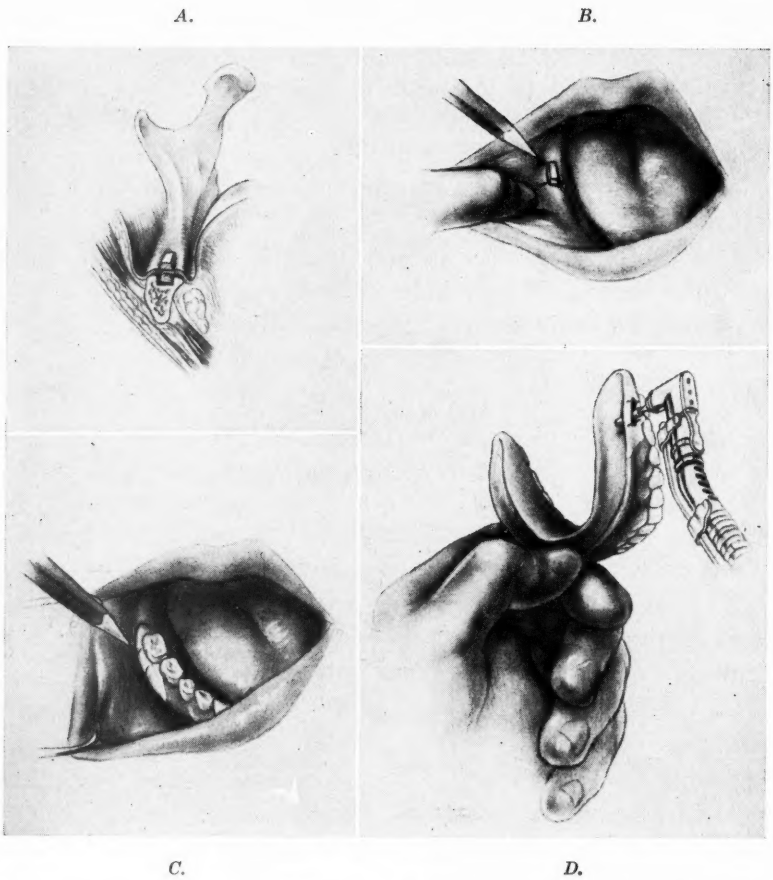


Fig. 18, *A* to *D*.—Prosthetic technique. *A*, The denture magnet *aligns itself* directly over implant magnet. *B*, The mucosa is marked. *C*, The markings are transferred to the denture. *D*, A "window" is cut through the denture.

Approximately 1 month after insertion of the implants, new dentures are constructed. (If it is felt that the present dentures are as good as can be made, the lower denture should be relined to accommodate to the tissue changes secondary to the surgical operation.)

INSERTION OF DENTURE MAGNETS

The lower denture is removed from the mouth; the upper denture is kept in place.

The denture magnets are placed on the mucosa in each molar area. They will align themselves magnetically directly over the implants in the bone. It is impossible for the denture magnets not to assume their correct position (Fig. 18, *A*).

The mesial and distal aspects of the denture magnets are marked on the buccal mucosa with an indelible pencil (Fig. 18, *B*). The "top" of the magnet should be marked with a pencil for identification.

The magnets are removed, the denture is inserted, and the markings are transferred from the tissue to the denture (Fig. 18, *C*).

The denture is removed and, using the markings as a guide, a "window" is cut through each buccal flange. The windows, substantially larger than the magnet, are cut beyond the markings, but the border of the flanges is preserved (Fig. 18, *D*).

Because the new magnets are so powerful that they cause displacement of the tissue, a single layer of green casting wax (30 gauge) should be applied to the bottom or tissue-bearing surface of the denture magnet (Fig. 18, *F*).

The denture is placed in the mouth and the magnets, with the wax identifying the bottom, are placed in the windows. The magnets will attempt to align themselves over the implants in the bone. Any interfering contact of the denture with the magnets must be removed. (The clear acrylic resin flanges permit better visibility.) When the magnets are resting on the tissue, and are not touching the denture at any point, they are properly aligned (Fig. 18, *E* and *F*).

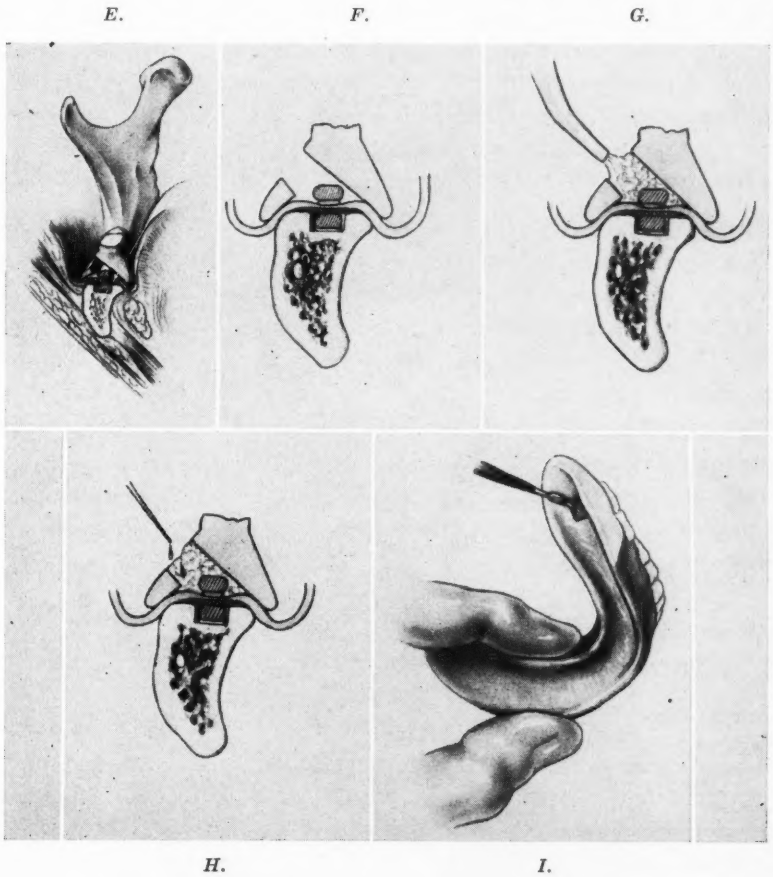


Fig. 18, *E* to *I*.—*E*, The denture magnet placed through the window aligns itself over the implant magnet. *F*, Note the casting wax temporarily placed on the bottom of the denture magnet to compensate for tissue compression. *G*, Polymer is insufflated. *H*, Monomer is applied. *I*, The undersurface is smoothed with the brush technique.

With the dentures still in the mouth, self-curing acrylic resin powder (polymer) is placed around the magnet in the window (Fig. 18, *G*). (Polymer powder in a medicine dropper is insufflated conveniently into place.)

With the teeth together in centric occlusion, droplets of self-curing liquid (monomer) are placed on the powder (Fig. 18, *H*). The addition of polymer and monomer is repeated until the windows are filled. Time is allowed for curing or setting, with the patient maintaining centric occlusion.

The dentures, now containing the denture magnets, are removed from the mouth. The layer of wax is removed. Any imperfections in the tissue-bearing surface are corrected by using a brush technique to add small amounts of polymer and monomer (Fig. 18, *I*). While the resin still is soft, the dentures are placed in the mouth as if doing a relining procedure. The bottom of each magnet should be an integral part of the smooth impression surface of the denture.

POSTINSERTION CARE

There will be no more pressure on the tissue between the magnets than on that under any other part of the denture. The denture is adjusted and cared for as any other denture except that *immediate attention* must be given to areas of irritation if they develop over the implant.

ALTERNATIVE PROSTHETIC TECHNIQUE

Each dentist may modify the suggested technique to his own demands. For example, at one point Egan would place the dentures in the mouth during the wax-up stage, and roentgenograms would be made. The tooth or teeth overlying the implant would be removed from the denture. After processing, the window was cut through the denture base in this planned edentulous area. The denture magnet would be inserted as described previously. The teeth would then be placed in their proper position in the denture, using self-curing methyl methacrylate.

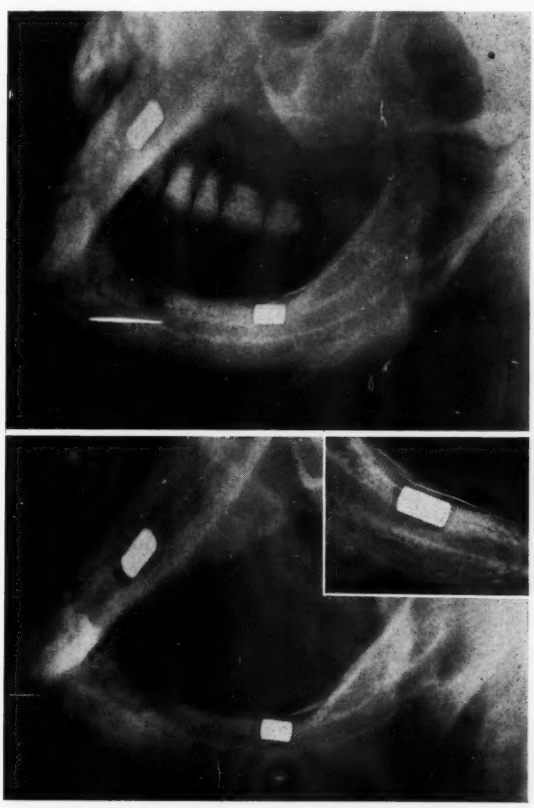
The denture magnets *must* be inserted directly. Any indirect method involving transferring of magnets to impressions and casts will produce some shifting of their positions. These changes, no matter how minute, will cause a decrease in magnetic attraction.

What Would Be the Long-term Reaction of the Tissues to This Technique?

PATIENT REACTION

Patients readily comprehend the theory of this technique and find it very appealing. This understanding of the fact that magnetic attraction will help hold their dentures in place makes them better denture wearers psychologically. The amount of increase in denture retention varies from patient to patient. A patient who can barely open his mouth without lifting of the conventional denture may find that he now can open it widely, stick out his tongue, and move his lips, tongue, and jaw in any manner without the denture unseating. Mastication can

Fig. 19.—An area opened for examination after 6 months (case 2). The arrow indicates new bone grown around the margins of the implant.



A.

C.

B.

Fig. 20.—Roentgenograms of the patient in case 1. *A*, Three years after implantation. *B*, Seven and one-half years postimplantation. *C*, A dental roentgenogram of *B* (see Fig. 9).

become as efficient as that of any patient wearing a complete denture. One patient had fourteen lower dentures in 14 years and was substantially underweight. She gained 8 pounds the first 4 months after implantation and reported 5 years later that her problem was currently one of becoming overweight (see case 7).

GROSS REACTION OF THE SOFT TISSUES

The mucoperiosteum overlying the implants shows absolutely no gross changes even after 8 years. It is impossible to tell by looking into the mouth whether or not the patient has magnets implanted in the jaw. It is essential, however, that the denture (or magnet) be relieved at the first sign of tissue irritation over the implant. "Sore spots" may develop at any area. Regardless of their size, ulcerations over bone will granulate and heal. Small ulcerations of the mucosa over the implant also will granulate and heal. Large ulcerations of some duration may permit downgrowth of epithelium into the vault (see case 7). If this occurs, the implant will become loose and should be removed (simply grasp it with a clamp and extract it). The area will heal and, several months later, the implant may be replaced.

GROSS REACTION OF THE BONE

One of the most exciting findings of this study became known in June of 1953. The second set of implants had been placed in December, 1952 (Table I, case 2). These were polytetrafluoroethylene-coated, flattened magnets magnetized through the diameter. After they were placed in the vault, a section of tantalum mesh was placed over them. The patient complained that there was "too much" tantalum mesh present. He said he could "feel" the mesh if he pinched the overlying mucosa with his fingers and he wanted some of it removed. Action was deferred for 6 months, during which time the implants were in place, the mucosa appeared normal, and dentures were worn comfortably. Six months after insertion, the overlying mucoperiosteum was incised and separated from the tantalum fibers with great difficulty. When the mucoperiosteum was elevated, it revealed the implant to be covered with a fibrous tissue sheath; but, instead of lying loosely in the vault as had been anticipated, the implant was held in place firmly *by bony growth around the edges of the implant* (Fig. 19). In order to remove the implant for inspection, the margin of new bone had to be removed with hand chisels and burs! This finding was repeated when, 13 months after insertion, the rotated magnet in the mandible of the patient in case 3 (Table I) was removed for replacement. (It was obvious at this point that, with the growth of bone holding the implants in position, no "reinforcement" of the overlying mucoperiosteum with tantalum mesh was necessary.)

In none of these cases has there been any indication of significant bone resorption. Even after 7 years, roentgenograms show bone about the magnets. Any radiolucency is accounted for by the plastic coating and the fibrous tissue capsule which envelopes all implants (Fig. 20, *C*). Where large amounts of tantalum were used, there is substantial fibrous tissue about the mesh (Fig. 20, *B*).

MICROSCOPIC TISSUE REACTION

Specimens of tissue have been obtained from 2 patients (see Table I, cases 2 and 3), one after 6 months, the second after 13 months. In no instance was there inflammatory reaction; the tissues around the tantalum mesh and that encapsulating the magnets were normal and uninflamed. Fig. 21 is a photomicrograph of tissue surrounding tantalum mesh after 6 months (case 2). Spindle cell fibroblasts can be identified; they are compressed where the tissue was torn in removing the

Fig. 21.

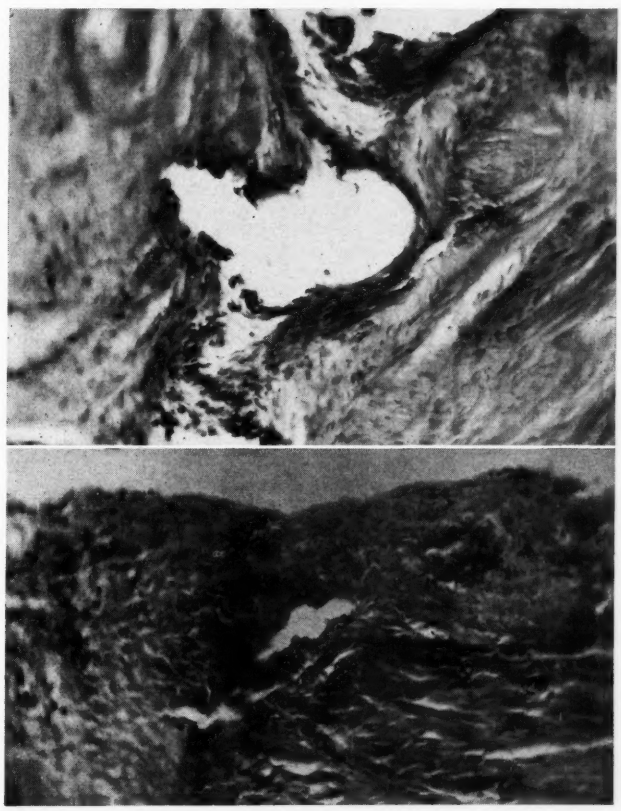


Fig. 22.

Fig. 21.—A microscopic section of tissue about a tantalum mesh after 6 months (case 2).
Fig. 22.—The tissue about an implant magnet after 13 months (case 3)

mesh. Fig. 22 is a photomicrograph of the tissue encapsulating a magnet after 13 months (case 3). Again the presence of fibroblasts and the absence of inflammatory tissue is noted.

Since these magnetic implants adhere to all the principles and precepts of implantation, there seems to be no reason why they will not remain in place indefinitely.

TABLE I

CASE NO.	SEX OF PATIENT	AGE OF PATIENT	DATE	MAGNET		MESH		COMMENT	FOLLOW-UP
				SHAPE	COATING	ATTACHMENT	COATING		
1	M	53	April, 1952	Cylindric	Acrylic resin	Separate	Raw	First platinum-cobalt implant	Excellent (see Case History 1)
2	M	53	December, 1952	Flat	PTFE*	Separate	Raw	First flattened magnet, first magnetized through diameter, first polytetrafluoroethylene coating; opened for histopathologic examination (Fig. 21); bone grown around margins (Fig. 19)	Good; dissatisfied with upper denture which is "loose" by comparison
3	F	50	December, 1952	Flat	PTFE	Separate	Raw	Magnet rotated after insertion; first to be replaced; histopathologic examination of tissue (Fig. 22); bone grown around margins	Fair; now unhappy over being "experimental"
4	F	62	February, 1953	Flat	PTFE	Separate	Raw	First sutures to keep mucosa and periosteum together	Good; now abroad, lost to follow-up
5	M	50	April, 1953	Flat	PTFE	Attached	PTFE	First "attached" mesh and magnet	Excellent; deceased 1957, autopsy not permitted
6	F	56	May, 1953	Flat	PTFE	Attached	PTFE	No antibiotics used; no primary healing	Poor health precluded further trial
7	F	48	December, 1953	Flat	PTFE	Attached	PTFE	Fourteen lower dentures in 14 years previously; decubital ulcer over implant; implant replaced	Excellent (see Case History 7)
8	F	50	December, 1954	Flat	PTFE	Attached	PTFE	Defective magnet used unwittingly; injury to mental nerve by metal retractors	Poor; defective magnets removed elsewhere 1958; no histopathologic study
9	F	47	December, 1954	Flat	PTFE	Attached	PTFE	First use of sutures alone for retraction	Excellent; periodic follow-up
10	M	50	July, 1956	Flat	PTFE	Attached	PTFE	Motion picture demonstration; implants pulled out of vaults by denture magnets immediately after surgical operation	Magnets not replaced to date because of incidental ophthamologic disease; will be replaced as soon as physical condition permits
11	F	48	November, 1956	Flat	PTFE	Attached	Raw	First attached uncoated mesh; impacted third molar removed at time of insertion	Excellent (see Case History 11)

*PTFE=Polytetrafluoroethylene.

SELECTED CASE HISTORIES

The implantation of magnets in the jaw is a new procedure. Regardless of animal experiments and the weight of myriad implants placed elsewhere in the body, cautious clinical investigation was mandatory. Difficult denture retention problems were selected. Each patient was followed and the case reviewed with the object of improving the method. The lessons learned with each case were applied to the next. In Table I, 11 consecutive cases utilizing platinum-cobalt magnets are listed with comments as to their contribution to the present implant and method.

Case 1.—This case, the first, has been described under the heading "Platinum-Cobalt Clinical Trial." Figs. 8, 9, and 20, *A*, *B*, and *C*, show roentgenograms of the implant over a 7 year period. To date, after 8 years of continuous wear, there are no gross tissue alterations and denture retention is excellent.

Case 7.—On Nov. 19, 1953, a 48-year-old housewife was seen with the chief complaint of inability to wear her lower denture. She had had fourteen complete lower dentures constructed during the preceding 14 years. Her present denture was worn with a soft reline pad which the patient replaced frequently. The embarrassment produced by her inability to keep the dentures from moving about caused her to become virtually a recluse. Inadequate masticatory function was responsible for her being underweight. Examination showed a thin, edentulous, poorly nourished woman with an extremely resorbed mandible. Various surgical procedures had so affected the bone that there was a depression or concavity in lieu of a residual alveolar ridge. The slightest motion of the tongue or opening of the mouth displaced the lower denture.

After the routine examination and consultation with her physician, the patient was prepared for surgical operation. On Dec. 3, 1953, 800,000 units of penicillin was administered intramuscularly and 0.2 Gm. of sodium pentobarbital and 0.6 Gm. of aspirin were given by mouth. Under mandibular block anesthesia, a magnetic implant was placed in the right side of the mandible. The postoperative course was uneventful. The left implant was placed in a similar fashion on Dec. 16, 1953. One month later a set of complete dentures was constructed by Egan. Denture magnets were placed in the dentures in the prescribed manner.

On May 7, 1954, less than 4 months after the insertion of the dentures, the patient reported that she was extremely happy and comfortable (Fig. 23, *A*). She had gained 8 pounds and ate a varied diet which included previously unmanageable foods, such as apples and crackers with peanut butter. Approximately 4 months later motion pictures were taken to demonstrate the difference in retention between the dentures with the magnets and without the magnets. Late that night, after completion of the film, the magnets were replaced in the denture very hastily and the patient rushed to a train. Several weeks later she appeared with a large decubital ulcer exposing the implant on the right side. This was observed for several weeks. On Nov. 9, 1954, the implant easily was lifted out of the tissue. A portion of the tissue was removed for histopathologic examination. This showed some downgrowth of the epithelium and connective tissue with a "moderate chronic inflammatory reaction." The area was permitted to granulate, and 1 month later the implant was reinserted in the usual manner.

The patient was seen recently, almost 6½ years since implantation. She is wearing the same set of dentures; the retention is excellent. Roentgenograms (Fig. 23, *B* and *C*) show excellent condition of the bone. The importance of prompt relief of sore spots was brought out in this case. This happy, comfortable patient's principal concern now is to keep from being overweight.

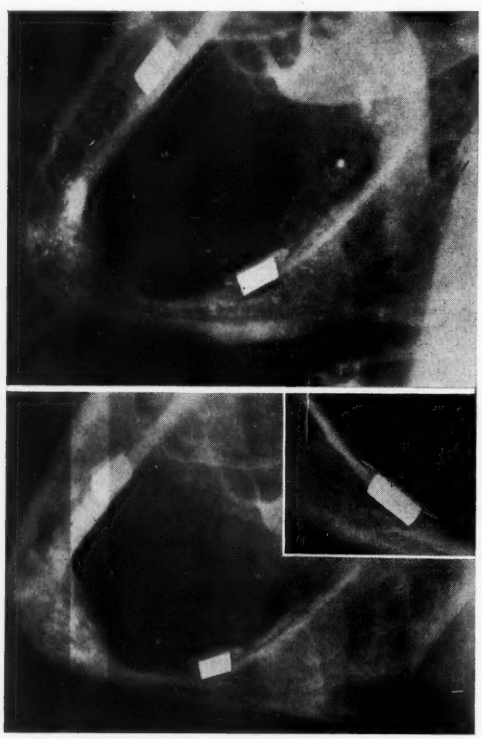
Case 11.—On Oct. 24, 1956, a 48-year-old woman was seen with the chief complaint of inability to keep her lower denture in place. Over the preceding 6 years she had had two sets of complete lower dentures (she wore a partial upper denture) and always had difficulty

*PTFE=Polytetrafluoroethylene.

maintaining them in position. Examination showed a markedly resorbed mandible. Minimal motion of the lips or tongue produced displacement of the lower denture. Roentgenograms revealed a lower right third molar impacted low in the ramus.

On Nov. 9, 1956, after antibiotic, sedative, and analgesic premedication and under local anesthesia, the impacted molar was removed. A magnetic implant was placed in the first molar area in the usual manner (Fig. 24, *A* and *B*); the left implant was placed similarly. The postoperative course was benign. One month later the patient returned to her dentist, who made a set of complete upper and lower dentures. Denture magnets were placed in the lower denture in the prescribed manner. However, the patient did not experience the expected improvement in denture retention. Several consultants pointed out that the denture was overextended to the extreme and that the occlusion was very eccentric. The overextension was reduced with some improvement. With the improvement in retention, the patient began to complain bitterly of soreness. This was attributed to the faulty occlusion. When occlusal adjustment provided relief in one area, a new sore spot would develop in another area.

A.



C.

B.

Fig. 23.—Roentgenograms of the patient in case 7. *A*, At implantation. *B*, Five and one-half years postimplantation. *C*, A dental roentgenogram of *B*.

The patient left for an extended vacation. She returned exhibiting a long-standing decubital ulceration over the implant on the left side. The occlusion was such that closure in working or balancing occlusion pushed the denture out of position. When the teeth were separated, the magnets realigned the denture with the ridge. This constant friction produced sore spots and eroded the mucosa. Ulcerations over bone healed; the ulceration over the implant did not. The implant was lifted out of the tissues on May 15, 1957. The defect granulated,

and on July 17, 1957, the implant was replaced. With the permission of the original dentist, the patient had another lower denture made by another dentist. The denture magnets were inserted and once again the results were below expectation. Consultation pointed out that this new lower denture was very much underextended, with the teeth improperly set. A new lower denture was constructed by another dentist. The patient noticed improvement

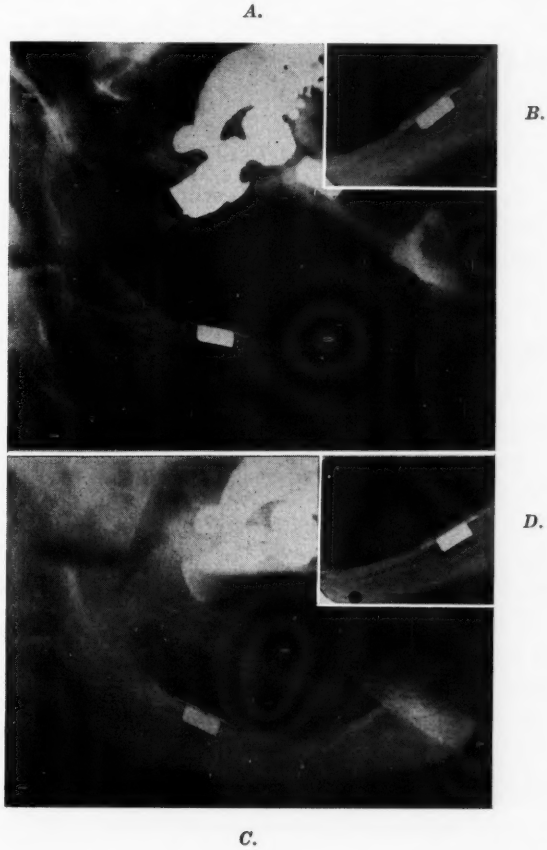


Fig. 24.—Roentgenogram of the patient in case 11. *A*, At implantation. *B*, A dental roentgenogram of *A*. *C*, Two and one-half years after implantation. *D*, A dental roentgenogram of *C*.

even before the denture magnets were placed. She wore the denture without the magnets for several weeks. The purpose of this was to make vivid whatever improvement, if any, would result from the implants. When the denture magnets were placed, there was additional marked improvement of denture retention.

This case emphasizes the absolute necessity for good prosthetic technique. Rather than overcome prosthetic inadequacies, this magnetic implant method may, in fact, exaggerate them. In this instance, without the magnetic force pulling the denture against the tissues, the shifting which resulted from the improper occlusion did not produce appreciable soreness. With the magnetic attraction, however, what might have been denture "slipping" became denture "rubbing," and the increased friction produced increased discomfort. Only with the construction of a good set of dentures did the patient experience the additional retention produced by the magnetic implants (Fig. 24, *C* and *D*).

THE FUTURE

A question that is asked frequently concerns the use of a third implant in the anterior portion of the mandible. Although some smaller magnets were fabricated with this in mind, they have never been used, because retention has been improved sufficiently with two implants. This experience does not preclude the use of three implants, but only indicates that I have not found it necessary.

I have not attempted upper implants. Retention of lower dentures is the larger problem and the aim has been to develop and improve this implant method. However, Zepponi,* in Rome, has inserted some magnetic implants into maxillae. There seems to be no reason why the technique cannot be modified to permit implantation in the upper jaw.

Georgiade† at Duke has been doing some work with excellent portent. He has placed magnetic implants in bone grafts replacing resected portions of the mandible. The future of magnetic implants in maxillofacial prostheses appears to be promising.

SUMMARY AND CONCLUSIONS

A technique for the implantation of magnets in the jaw to aid denture rerention has been presented. The physical, physiologic, and anatomic background, including the underlying principles of implantation, have been discussed. Animal experiments have been reported and the early clinical trials recounted. The surgical and prosthetic techniques have been described in detail. The results with several patients have been presented.

Eight years of follow-up have shown the complete safety of implanting magnets in the jaw when the outlined diagnostic criteria and surgical techniques are followed carefully. There have been no adverse physiologic effects. Gross and microscopic tissue findings have been excellent; roentgenographic evidence has been most favorable. Denture retention has been enhanced and patient reaction has been encouraging. Four hundred and fifty Behrman Magnetic Implants had been placed up to Aug. 1, 1960; forty-five by the author.

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INTEROCCLUSAL RECORDS

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ALTHOUGH DENTISTRY HAS RECOGNIZED the importance of accurate interocclusal records, these were most frequently made in wax. Waxes, at best, rendered only approximate accuracy in these records. This study was made to compare the accuracy of wax records with a record made in a cold-cure acrylic resin.

WAX RECORDS

Upper and lower casts of natural teeth were mounted in centric occlusion on an articulator. A wafer of impression wax* was evenly heated in water until it was soft and workable; then it was placed over the occlusal surfaces of the lower teeth on the cast. The articulator was closed with a 10 pound weight on the arm. The weight was allowed to remain there until the wax hardened (Fig. 1).

Afterward, the upper cast was remounted on the articulator by means of the wax record. Then, the occlusion determined by the wax record was compared with the centric occlusion of the original mounting. A noticeable discrepancy between the original centric occlusion and the occlusion established by the wax record was apparent. This indicated that the occlusal relationship had been changed as the wax record was made.

The control post in front of the anterior teeth was then closed to the new occlusion. The wax record was replaced on the lower cast and the articulator was closed. The control post, which had been in contact without the wax record, was now raised 2 mm., indicating that the upper cast was not in contact with the lower cast when a pressure of 10 pounds was applied (Fig. 2).

In a previous study,[1] it was shown that the mandible does not normally open or close on a hinge axis. Therefore, a decrease made in the vertical dimension on an articulator introduces an error.

OTHER WAX RECORDS

Two additional wax records were made under different pressures by use of the same casts in centric occlusion. A second wafer of impression wax was heated and placed over the occlusal surfaces of the lower cast. The articulator was closed, and a *10 ounce* weight was placed on the upper arm of the instrument (Fig. 3). The imprint of the cusps in the wax was slight. The articulator remained open, which indicates that a slight pressure on soft wax is ineffective (Fig. 4).

*Aluwax.

Next, a *30 pound* weight was applied to the softened wax and this pressure maintained until the wax hardened (Fig. 5). The upper cast was then remounted to this record. When the record was removed and the articulator was closed, there was a discrepancy between the original centric occlusion and the occlusion established by wax record. This indicated that the occlusal relationship had been changed in making this wax record.

The anterior control post was closed to the level of the new occlusion. The wax record was replaced on the lower cast and the articulator closed. The anterior control post showed a separation from its seat with the wax record in place (Fig. 6).

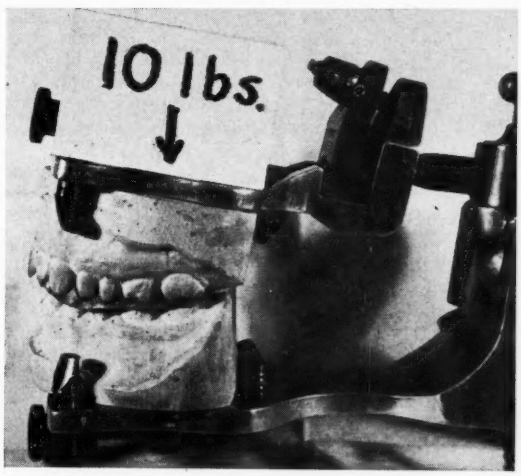


Fig. 1.—An interocclusal record is made with impression wax under 10 pounds of pressure.

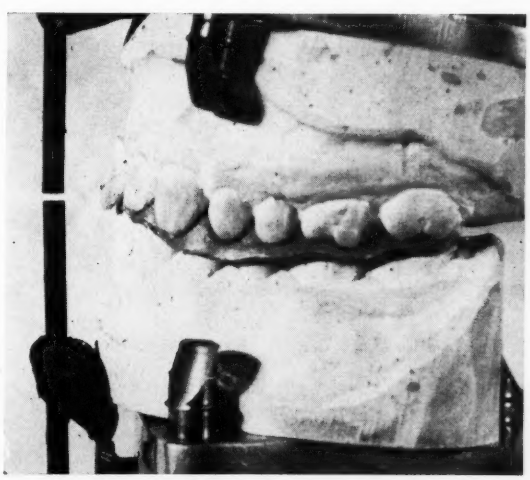


Fig. 2.—A 2 mm. separation of the control post exists when a wax record made under 10 pounds of pressure is in position. The occlusion does not coincide with the original centric occlusion.

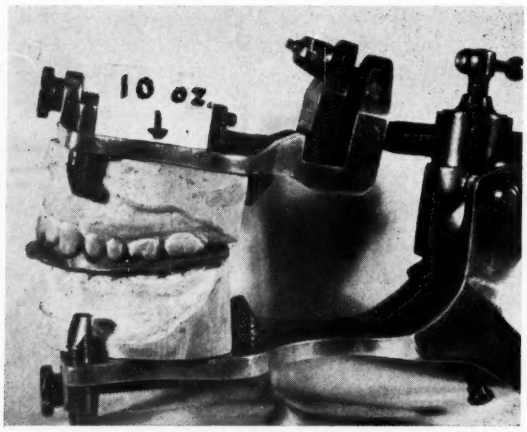


Fig. 3.—An impression wax interocclusal record is made under 10 ounces of pressure.

AN UNUSUAL PHENOMENON

The interocclusal record made under 30 pounds of pressure was transilluminated by being placed in front of a light. A great many perforations could be seen in the wax. This indicated that many occlusal contacts had occurred when the record was made. When the upper cast was remounted to this record, however, the teeth were out of occlusion. The control post did not reach its seat when the record was removed. This indicates that wax is not an accurate material for making interocclusal records.

When baseplate wax was substituted for the relatively soft impression wax, the discrepancies were even greater. The baseplate wax was somewhat harder, and

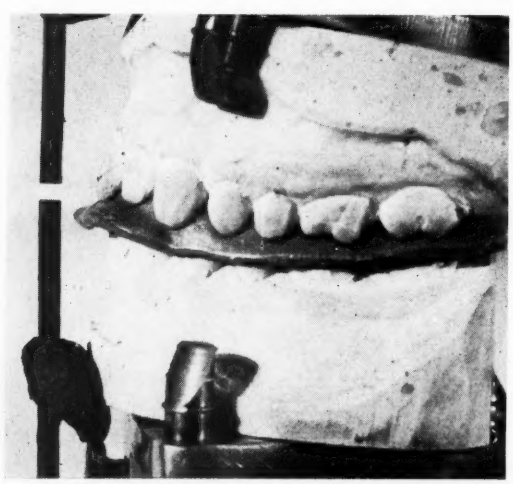


Fig. 4.—A large separation of the control post indicates the ineffectiveness of 10 ounces of pressure on soft impression wax.

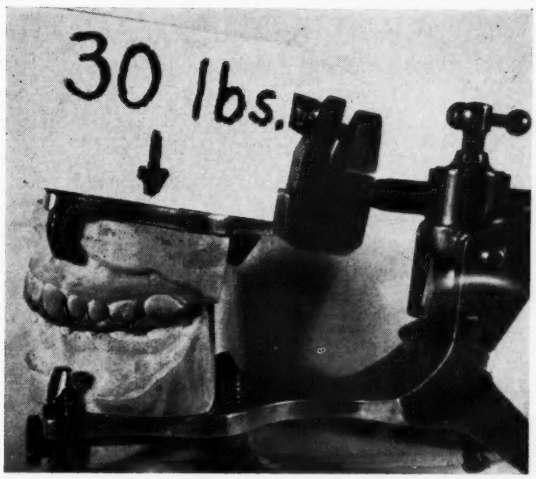


Fig. 5.—An impression wax interocclusal record is made under 30 pounds of pressure.

therefore it required additional pressure to make the record. Regardless of the amount of pressure, an interocclusal wax record does not permit the complete seating of casts in centric occlusion on an articulator.

PREPARATION OF RESIN

Soft plastic strips are produced for use in making interocclusal records. Molds for fabrication of the strips are made by turning up the ends of the metal backs used for carding teeth. After the molds are lubricated with petroleum jelly, they are filled with a cold-cure acrylic resin powder and barely saturated with the liquid

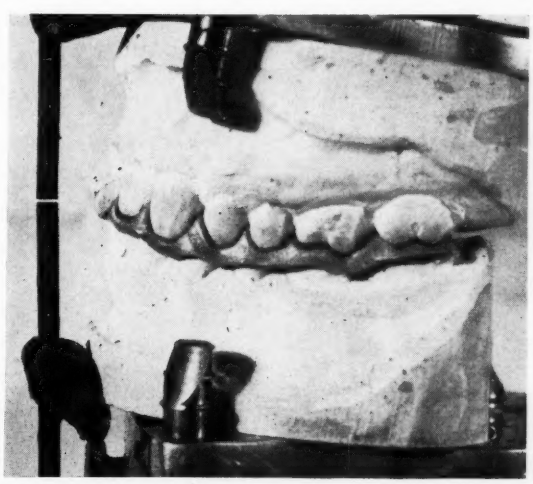


Fig. 6.—The separation of the control post that exists with a wax record made under 30 pounds of pressure is shown. A discrepancy exists between the original centric occlusion and the occlusion obtained from the wax interocclusal record.

monomer. When the sheen disappears from the surface of the resin (generally in 2 minutes), the soft plastic strips are removed from the molds and are ready for use. The strips should be between 1 and 2 mm. thick.

ACRYLIC RESIN INTEROCCLUSAL RECORDS

To obtain an acrylic resin interocclusal record of one side of the dental arch, a piece of thin cellophane is folded over a soft resin strip. The long, free ends of the cellophane are held with an instrument, such as a Miller carbon paper holder, and the strip is placed over the occlusal surfaces of the teeth. The patient is instructed to close the mouth gently into centric occlusion, and the holder is removed. The resin is allowed to set, which generally takes 3 minutes.

To obtain an interocclusal record on both sides at the same time, the soft resin strips are placed over the occlusal surfaces of the lower teeth on both sides. To facilitate their placement, the soft plastic strips are placed between two thin sheets of cellophane that are attached to a sturdy wire frame.

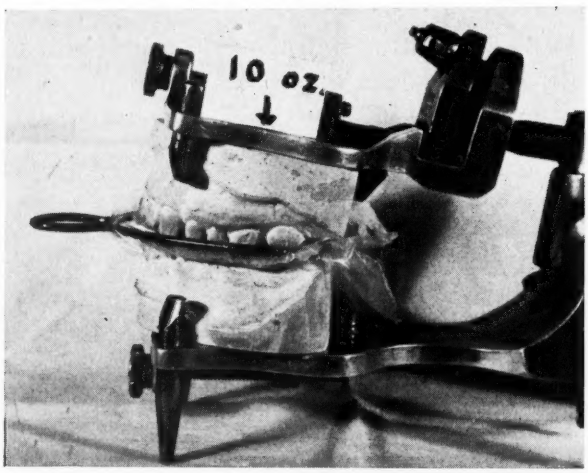
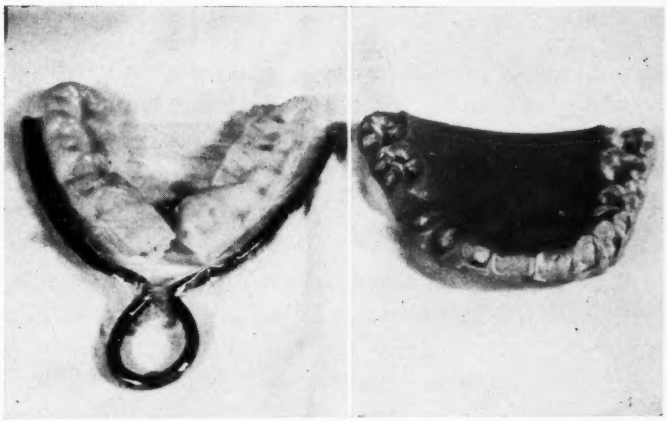


Fig. 7.—A cold-cure acrylic resin interocclusal record is made under 10 ounces of pressure.

The cellophane serves as a carrier and prevents the resin from being forced into deep sulci and undercuts. Cellophane also prevents the stone teeth from fracture when the articulator is opened, and it makes remounting easy.

ACRYLIC RESIN TESTS

After the soft resin strips were positioned over the lower stone teeth on the articulator, the upper arm of the instrument was closed and a *10 ounce* weight was placed on it until the plastic record had set (Fig. 7). Soft resin, unlike soft wax, offered little resistance, and even under a 10 ounce weight, the recording material oozed gently away from the closing cusps until the teeth were in light contact in centric occlusion (Fig. 8).



A. *B.*

Fig. 8.—*A*, A wire frame, acrylic resin strips, and cellophane are used to make the record. *B*, An impression wax record.

After the plastic had set, the cellophane was removed from the records because its purpose had been served. Its removal has no clinical bearing on the final result.

The upper cast was remounted according to the acrylic resin interocclusal record. Upon removal of this record, it was found that the original centric occlusion and the occlusion obtained from the plastic interocclusal record appeared to be very nearly the same. There was a slight separation of the control post from its seat, however, when the record was in position (Fig. 9).

Fig. 9.—A slight hairline separation of the control post exists with the acrylic resin record made under 10 ounces of pressure. There is no discernible discrepancy between the original centric occlusion and the occlusion determined by the resin interocclusal record.

CONCLUSION

Baseplate wax and impression wax do not make satisfactory interocclusal records for mounting casts on an articulator. Cold-cure acrylic resin is preferable for this purpose because casts can be mounted more nearly in centric occlusal contact than with wax.

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CENTRIC RELATION—THEORY AND PRACTICE

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WEBSTER'S *Collegiate Dictionary* defines "centric" as follows: "adj. 1. Placed in or at the center or middle; central. 2. Of, pertaining to, or characterized by a center." Is this definition in any way related to what is generally understood by centric in dentistry?

The *Glossary of Prosthodontic Terms*[1] gives this definition of centric relation: "The most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made, at any given degree of jaw separation."

The American Dental Association definition of 1955 is not unlike the one in the *Glossary.*

The only inference of a center may be in the phrase, "from which lateral movement can be made," and I doubt whether this was intended. However, I shall endeavor to show that the dictionary definition can very definitely be applied to the centric relation of dentistry.

With which center are we going to be concerned? There are literally millions of centers of mandibular movement. The problem depends on which movements are made and to what they are related. These centers are instantaneous and constantly changing with each slight movement.

We must concern ourselves with a center that can be easily located, that can be useful for our procedures—a center that will enable us to reproduce the patient's movements on a suitable articulator and execute our work more intelligently and with greater ease.

LOCATION OF THE CENTERS OF ROTATION

In order to locate this all-important center, it is necessary to reduce the jaw movements to their simplest form. The jaw can open and close in a hinge movement. This is not a normal movement, but it is one that the patient can be taught for the dentist's convenience. By teaching the patient this hingelike action, one can locate the center of this action and make use of it by reproducing the same center on an articulator.

That there is a hinge axis hardly requires any defense. It is now almost universally accepted. Its importance we will try to demonstrate. That there is only one axis will have to be accepted for the moment. It has been proved.

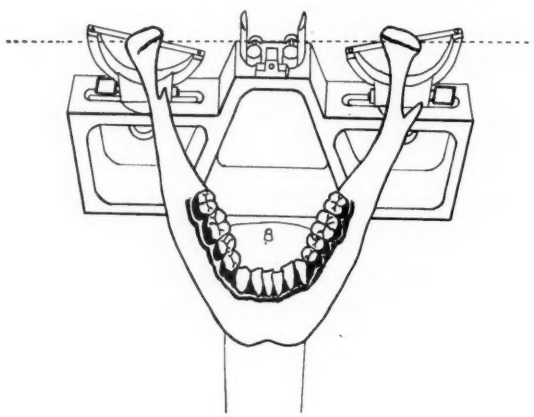
Read before the Greater New York Academy of Prosthodontics in New York, N. Y.

By locating the hinge axis, the center of vertical movement of the mandible is located. This enables us to place casts of the mouth on an articulator which will duplicate the opening and closing component of movement.

The mandible is also capable of lateral movement, and there is a center for this lateral movement. By the use of twin Gothic arch (needle-point) tracings in the horizontal plane, made outside the patient's mouth on either side of the midline, it is possible to locate the centers of lateral movement. These are located in the condyles and on the hinge axis. These centers can be duplicated on an articulator that has an adjustable intercondylar distance.

By these two procedures, *the* centers of rotation, both vertical and lateral, have been located and duplicated. When these centers are duplicated on an articulator and the paths of these centers reproduced, all the patient's mandibular movements can be very easily duplicated. All it now requires is a pair of hands to supply the muscular force and a mind to direct those hands.

Fig. 1.



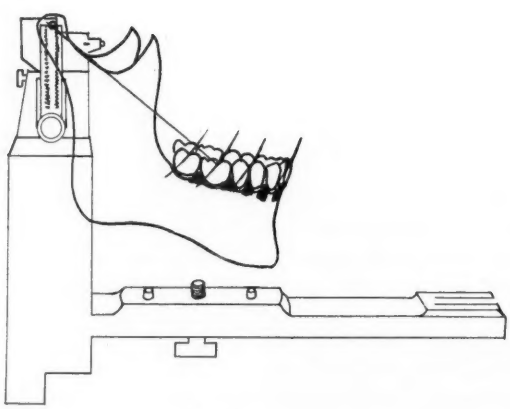


Fig. 2.

Fig. 1.—The relation of the lower teeth (and mandible) to the hinge axis of the articulator.
Fig. 2.—The relation of the lower teeth to the arc of closure of the articulator. The use of the hinge axis permits these arcs to be identical with those of the patient's mandible.

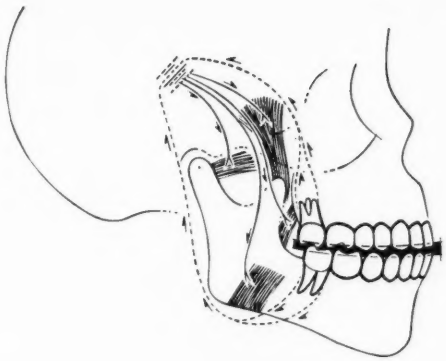


Fig. 3.

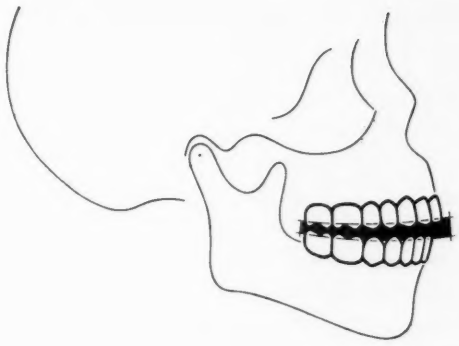


Fig. 4.

Fig. 3.—A schematic drawing showing the mechanism involved when a proprioceptive stimulus comes into play as the second molars penetrate the wax and make a premature contact. This reflex act will preclude the possibility of a terminal hinge closure.

Fig. 4.—An attempt to block out the proprioception is made with a thick wax wafer. The use of such a wafer requires hinge axis–mounted casts.

It becomes necessary to think of the centers of rotation as made of two components, the center of vertical motion and the center of lateral motion. They are one and the same center—one in each condyle. These centers determine all the possible movements of the mandible. They are located in the condyles and travel wherever the mandible goes. They are the centers of its every movement. When these centers are in their terminal hinge position, the mandible is in centric relation to the maxillae.

How can these centers be located in a practical way?

The first component is the hinge axis—its location and use in mounting a set of the patient's casts so that they are on the same axis on the instrument as the teeth are in the mouth. It would serve no purpose here to review the steps involved in locating the axis. The relation of the axis to the important first component of centric relation—the relation of the lower cast to the upper cast in the correct arc of closure (Figs. 1 and 2)—should be pointed out, however.

In order to record the mandible's path of vertical movement in the terminal hinge position, the patient must be deceived. The dentist has to block out all the proprioceptive impulses which direct the movements. The proprioceptive impulses are responsible for the awareness of the position of the mandible in space. The impulses guide the mandible in its habitual movements. The reflex actions that take place are reinforced by the proprioceptive stimuli. One of the natural reflex acts of the mandible is to close into a lateral or a lateral protruded position when something is introduced into the mouth (Fig. 3). This is what happens when a material such as wax is placed in the mouth and the patient is told to bite. It is necessary to obtain a relationship of the terminal hinge action without any lateral deviation. One practical way of blocking out the proprioception is to prevent the teeth from coming together (Fig. 4). The relationship of the mandible to the maxillae in the terminal hinge position without tooth contact must be obtained. Consequently, the patient must be trained and guided to execute the terminal hinge action.

RELATION OF THE MANDIBULAR CAST TO THE MAXILLARY CAST

Having located the hinge axis of the patient and having made an accurate transfer of the maxillary cast to this axis on the articulator, next the mandibular cast must be related to the maxillary cast.

This is accomplished by means of a two stage interocclusal record. A wafer made of a sheet of Tenax* wax on a sheet of Sure-Set† wax is softened in water at 130°F. The softened wax wafer is placed in the mouth, with the Tenax side upward (Fig. 5). The patient is guided into the terminal hinge "swing." When the patient is executing a hinge swing, he is permitted to close the teeth against the wax. The purpose of this first closure is only to get an indentation of the upper teeth on the wax wafer. The swing is merely for practice. Very slight indentations will be made on the harder, underneath wax.

The wafer is removed and chilled in water at room temperature. Now trim the wafer to the outside edge of the upper teeth to reduce its bulk, and also remove the anterior portion, cutting it off across the center of the cuspids. This will give a

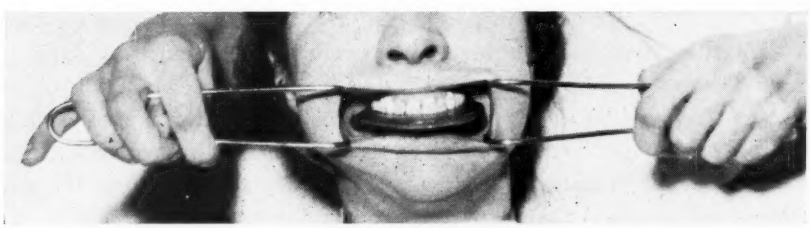


Fig. 5.—The upper layer of the wax wafer records the imprints of the upper teeth.

better view of what is happening in the mouth. Also, with the anterior teeth exposed, the thumb can be used as an anterior stop to the closure. Further, with the anterior portion of the wax removed, there are fewer tooth indentations to fit into the record. Thus there is less chance of error should there be a slight discrepancy in the duplicated anterior teeth on the cast.

Place the trimmed wafer on the patient's upper teeth (Fig. 6) and have the patient close firmly against the lower layer of wax (Fig. 7). This will readapt the wafer to the upper teeth. When it is determined that there is an accurate seat against the upper teeth, proceed to make the second stage of the interocclusal record.

Remove the wafer, dry it with a blast of air, and apply softened impression wax‡ to the underneath side. A ridge of soft impression wax is created on the arch of slight indentations previously made by the mandibular teeth. While the impression wax is soft (the rest of the wafer has not been affected because of the higher melting points of the two original layers of wax), the wafer is placed on the patient's upper teeth. Holding it in place with the thumb and index finger of the left hand and with the right thumb on the patient's chin, have the patient execute

*S. S. White Dental Mfg. Co., Philadelphia, Pa.
†Kerr Mfg. Co., Detroit, Mich.
‡Aluwax pencil, Hickok Specialties Co., Grand Rapids, Mich.

the terminal hinge swing (Figs. 8 and 9). When the swing is smooth and terminal, have the patient just *touch* the impression wax, quickly snap the jaw slightly open, and then close, making only the slightest imprint on the impression wax. It may be necessary to use additional wax and repeat the procedure.

Fig. 6.

Fig. 7.

Fig. 6.—The trimmed wax wafer is placed on the upper teeth.
Fig. 7.—The wax wafer is readapted by the patient's closure to correct any distortion that may have been caused by the trimming.

Fig. 8.

Fig. 9.

Fig. 8.—Softened impression wax has been applied to the mandibular side of the wax wafer and the patient's mandible is guided into a hinge closure.
Fig. 9.—The hinge closure is completed after several "swings" to be sure the mandible is in the posterior terminal hinge position.

After chilling the wax wafer, place it on the upper teeth and have the patient close again against the impression wax. Determine whether the patient can easily and readily fit the mandibular teeth into the slight indentations, also whether there is any play in the wafer while the teeth are closed against it. Finally, the patient

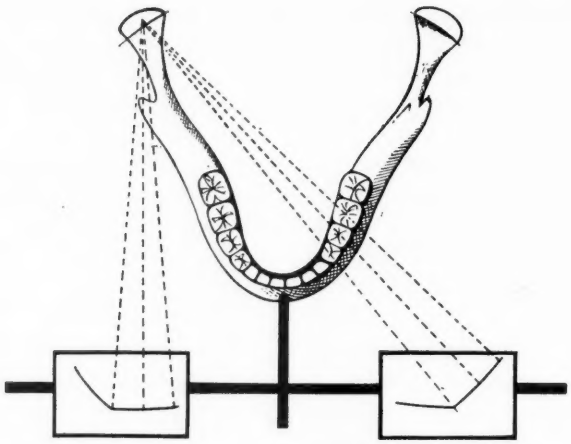


Fig. 10.—The relation of the center of lateral rotation to the respective wings of the two tracings.

should be asked whether the pressure is equally distributed, and it should be ascertained that there are no thin spots or penetrations on the wafer. If all of these tests are satisfactory, there is a relationship with the teeth separated. This relationship is transferred to the articulator.

In order to bring the teeth into contact on the articulator, the lower cast must travel toward the upper cast. Thus, unless the closure is made on the same arc as the patient's mandibular closure, the teeth will not contact correctly. The correct mounting of casts on an articulator definitely depends upon the location of the hinge axis of the patient and its transfer to the articulator.

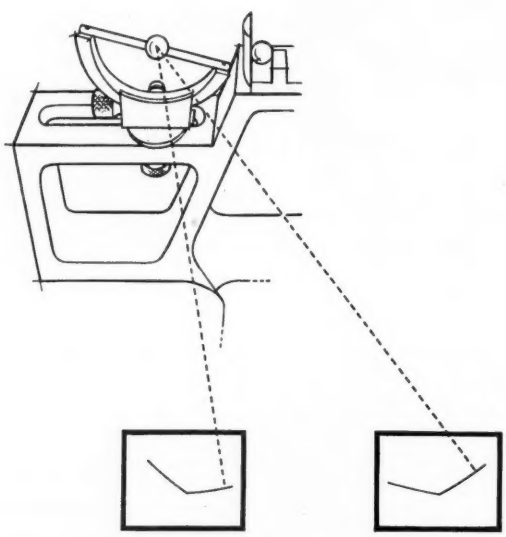


Fig. 11.—The wings of the tracings that were made on a patient are used to locate the center of lateral rotation on an articulator.

The procedure so far permits the correct apposition of the casts on an instrument in the opening and closing component, but only in the terminal hinge position. It is necessary to transfer the centers of lateral motion to an articulator if the other movements of the mandible are to be faithfully reproduced. As previously indicated, this is accomplished by the use of twin Gothic arch (needle-point) tracings (Fig. 10). On a suitable articulator which can be adjusted for intercondylar width, the centers of lateral movement are located from the twin Gothic arches (Figs. 11 and 12). All that remains now is to duplicate the paths of these centers and all possible jaw relationships will have been duplicated.

SUMMARY AND CONCLUSIONS

It is not the purpose of this article to do other than present a reason for duplicating these rotational centers. These centers control all the movements of the mandible. The centers in the terminal hinge position provide a definite starting position relation of the mandible to the maxillae (or their duplicates on an articulator). Once the dentist has obtained a reproducible relation of the mandible to the maxillae, he can proceed with confidence to establish the tooth relationship desired.

We have considered only the mandible-to-maxillae relationship. How the teeth are arranged when the mandible and maxillae are so related will depend on

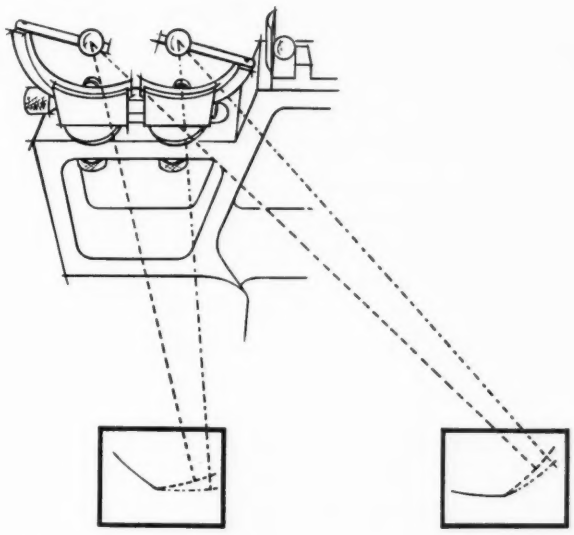


Fig. 12.—A composite drawing to show the different locations of the center of lateral rotation as determined by tracings from two different patients.

one's beliefs about centric occlusion and centric relation—whether these two factors should be in harmony or whether centric occlusion should occur slightly in front of centric relation. By having the centric relation of the mandible to the maxillae properly related on an articulator, the dentist can develop the centric occlusion accurately according to his own specifications.

It seems logical, from the anatomy of the temporomandibular joint, that the most stable position of the mandible is that in centric relation. The origin and insertion of the muscles of mastication, the inclination of the glenoid fossae, the function of the meniscus and synovial membranes—all indicate that any functional movements must seat the condyle in the terminal hinge position. Centric occlusion, therefore, should be built to occur at centric relation. Clinical evidence substantiates this belief. The best results are obtained when we succeed in correlating centric occlusion with centric relation.

Regardless of whether we believe that centric occlusion should be slightly anterior to this terminal hinge position, this is the only constant, repeatable position that can be used to check the work as we proceed. It is the only means for accurately relating the casts of the patient so that they can be examined in every detail, with true relationship to each other and without encumbrances of tongue, cheeks, saliva, and the patient's distracting proprioceptive reflexes. For those who do complete mouth rehabilitation, the hinge axis is as great a luxury as high-speed equipment.

These rotational centers may be mechanistic, but it is the physiologic application of these mechanical principles that will maintain the status of prosthetics in dentistry.

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THE ROTARY NATURE OF SOME MANDIBULAR MOVEMENTS

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After many years of work by many people, there is little real understanding of the nature of mandibular movements. One of the reasons for this is the confusion that arises from attempts to explain phenomena in language that is meaningless in relation to the particular subjects being discussed.

An example will help to make this point clear. A solid body, if it is rotating, does so about an axis, that is, an imaginary straight *line*. Although imaginary, this axis has a very real position in space, and in order to define this position, it is necessary to know the location of two points on it. Knowledge of the position of one point alone tells nothing about the direction in which the axis runs and, therefore, nothing about the direction in which the solid body is rotating (Fig. 1).

In spite of this, the majority of writers who attempt to describe a rotary movement of the mandible still persist in referring to a "center of rotation," in other words, to a *point* about which the mandible is supposed to rotate. Such descriptions are entirely without meaning and can only serve to confuse.

Another reason for the delay in achieving understanding of the subject has been the lack of a really satisfactory technique for its investigation. Tracing techniques are of value only when the tracing is made in the same plane as the movement under investigation.[1] If the tracing is not in the same plane as the movement, distortions occur which make interpretation difficult, if not impossible. This has led investigators astray, and similar difficulties are associated with other techniques that have been used.

If further progress was to be made, a new technique that did not depend upon any exact relation of the recording device to the plane of movement had to be devised.

The movements to be investigated were those performed with the teeth in contact and extending no further than the functional range. They were those movements responsible for the attrited facets produced on the teeth by (1) left and right lateral movements, (2) retrusive or retrocentric movements in the sagittal plane, and (3) protrusive or precentric movements in the sagittal plane.

METHOD

If a rapidly rotating body, such as a spinning top, is observed, there is little doubt as to what it is doing and the axis about which it rotates can be visually located with a fair degree of accuracy. If the top was moving very slowly, however,

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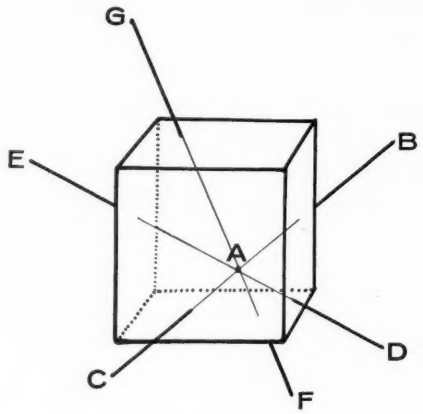

Fig. 1.—To say that this cube is rotating about point *A* in no way defines the direction of rotation, which could be about any one of an infinite number of axes passing through *A*. To say that the cube is rotating about the axis *BC*, or about the axis *DE*, etc., immediately defines the movement of the body, and the locus of every point in it can be worked out.

there would be greater difficulty in recognizing its movement as rotation. And, if we could only view it obliquely at an unknown angle, could only see a very small part of it, and were allowed to watch it while it made only a very small part of a complete rotation, we would probably fail to recognize its movement as one of rotation. The accurate location of its axis would be quite impossible.

Similar conditions apply to the mandible, and if the small movements it makes as the lower teeth slide against their opponents are rotary in nature, they cannot be recognized as such by simple observation.

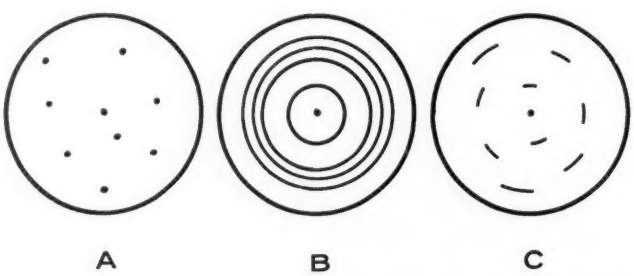

Fig. 2.—*A*, A stationary top viewed from above. *B*, The top in motion. The dots have merged themselves into circles around the axis. *C*, If the top stops after turning through only a few degrees and returns to its starting point, the circles are not complete and small arcs of circles around the axis are produced.

Consideration of a spinning top, however, leads to the understanding of how it may be possible to discover if the mandible makes such a movement. Fig. 2, *A*, is a diagram of a stationary top viewed vertically from above. Fig 2, *B*, shows the same top in motion, the dots having merged themselves into circles around the axis. This is the sort of picture that would be obtained by photographing the top from above, using a long exposure. The rotary motion is easily recognized,

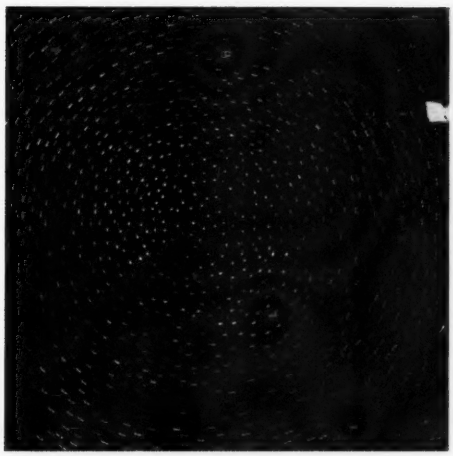

Fig. 3.—A typical rotation pattern as obtained with the method described (right lateral movement of subject C).

and the point where the axis emerges from the upper surface is clearly indicated. Fig. 2, *C*, shows the type of picture that would be obtained if the top stopped after it had turned through a few degrees and returned to its starting point. The circles are not now complete, in that the movement of the dots was only sufficient to produce small arcs of circles around the axis. Nevertheless, the movement is still recognizable as one of rotation.

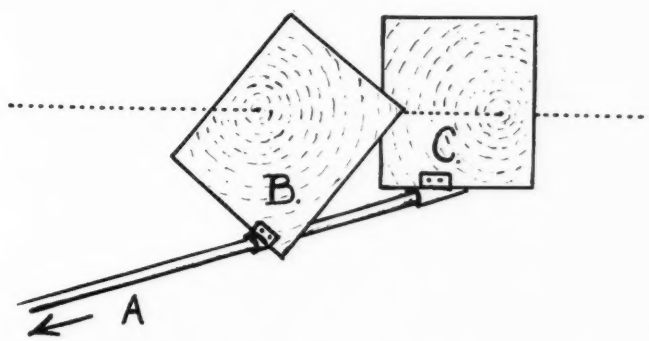

Fig. 4.—Diagram representing two screens *(B* and *C)* attached to a rotating body *(A)*. If the points at which the axis of rotation cuts the screens can be found, a line joining these gives the true position of the axis of rotation of the rotating body. The method can be applied even when the rotating body is out of sight, as in the case of the mandible. The method is not affected by the angles of the screens to the axis or their angles to each other, and they can be attached to any part of the rotating body.

From this it can be seen how photography can help to demonstrate small movements of the mandible. It is not possible to photograph the mandible itself during the small movements under investigation, but it is possible to photograph a light screen attached to it and moving as part of it. If the small movements it

makes are rotary, a picture similar to Fig. 2, *C*, will be obtained. Fig. 3 shows a typical photograph obtained in this manner. This demonstrates the rotary nature of the movement being performed.

In order to obtain such photographs as this, a chrome-cobalt splint was cemented to the lower teeth. This did not make any contact with the upper teeth. A light balsawood frame carrying a black paper screen covered with white dots was attached to the splint. The frame was adjusted until it was in such a position that the axis of the movement under investigation passed through it, and, during repetition of the movement, the screen was photographed using a long exposure. From the picture obtained, it was possible to locate the point at which the axis

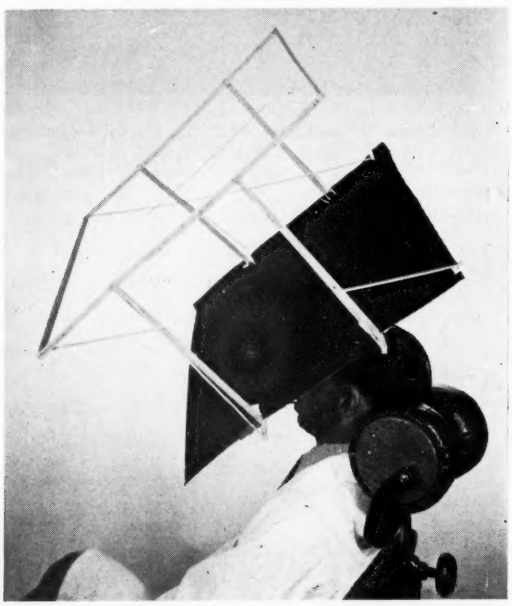

Fig. 5.—Practical application of the method shown in Fig. 4. The screen is photographed in the position shown and a second screen is then placed on the upper frame for photographing.

passed through the screen, but this was insufficient to fix the position of the axis. In order to do this, the process had to be repeated with a second screen placed some distance from the first (Figs. 4 and 5). When the points which had been pierced by the axis of movement had been located on both screens, a light rod was thrust through them. This rod extended along the axis of the movement.

The arrangement shown in Fig. 4 was found suitable for recording the axis position for right and left lateral movements. For protrusion and retrusion from the centric position, a modification of this approach was required. The axes of these movements are transverse, and to record them a screen must be placed on either side of the subject. Each screen can be simultaneously photographed then by a separate camera, so that during a given movement two simultaneous photographic records can be made. Where both screens are placed on the same side of the subject (as for lateral movements) only one screen can be photographed at a time,

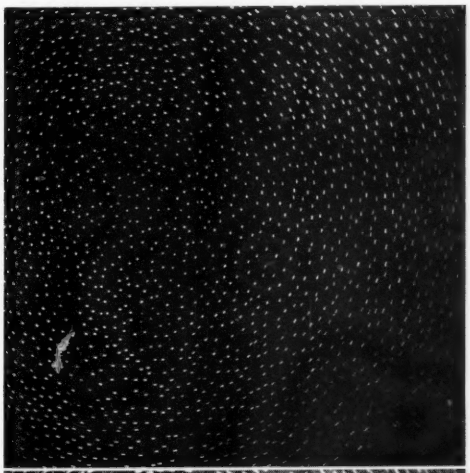

Fig. 6.

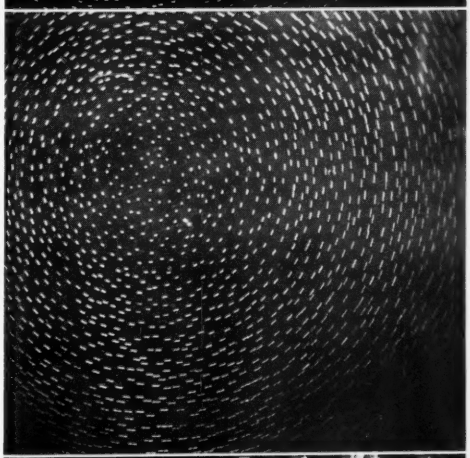

Fig. 7.

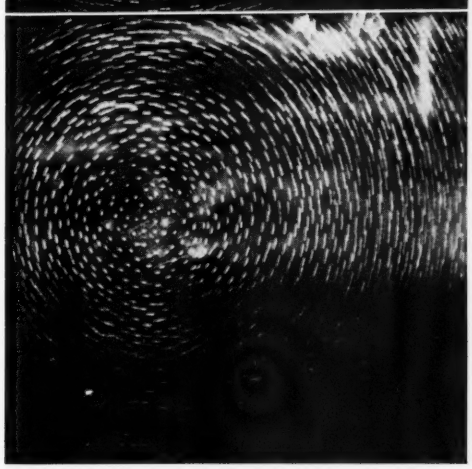

Fig. 8.

Fig. 6.—Retrusion from the position of centric occlusion (subject A). Location of the axis is difficult.

Fig. 7.—The same photograph as Fig. 6, treated by the method of superimposition. The point at which the axis cuts the screen can be more easily seen.

Fig. 8.—Fig. 6 after further treatment. The location of the axis position is now clear.

and there is a danger that the movement made during the photographing of the second screen may not be identical with that made during the photographing of the first. Certain precautions that must be taken to avoid this danger are described later in the article.

Enlargement of the Paths of Very Small Movements.—Some movements are so small that, although they produce typical rotation patterns, the lines are too short for easy location of the point through which the axis passes (Fig. 6). In these cases, two or more negatives are superimposed so that the beginning of the path of a dot on one corresponds with the end of its path on another (Fig. 7). This is found to clarify the picture very considerably, and the method could be repeated as often as necessary until the stationary point can be clearly recognized (Fig. 8).

This method provides proof that the paths produced during the photographing of a movement are actually arcs of circles, i.e., that the movement is one of pure rotation. If it is not, simultaneous superimposition of the ends of all the lines becomes impossible.

Advantage.—The advantage of this method is that the angle of the screen to the axis of movement is not of great importance. It can be at a right angle to it or set obliquely to it, and the result will not be affected in any way. Neither does the angle from which the screen is viewed or photographed have any significance. The same point will be observed to remain stationary and the rest of the points to move. The only difference that will be observed if the camera is set obliquely to the screen, or the screen obliquely to the axis, is that the paths traced by various points will appear to be elliptical rather than circular. This affects only the special method of enlarging very small movements. The enlarging method cannot be used if there is any distortion of this nature. It does not affect the method in general.

The use of one screen will enable the observer to detect whether or not the movement is one of rotation. The use of two screens will enable the position of the axis of rotation to be located by joining the stationary points on the two screens. This can be done whether both screens are placed on one side of the subject or one on either side of him.

Disadvantages.—The main disadvantage of the method is that the apparatus possesses weight that may interfere with the true movement of the mandible. The greatest weight of apparatus used was 190 Gm., but so strong are the muscles of mastication that this was practically unnoticed by the subject.

Mandibular movements made with the teeth in contact are far less likely to be affected by weight than free movements such as elevation and depression. During another investigation, however, it had been found that free movements were unaffected by alteration in the weight of the apparatus. Therefore, it was not felt that weight affected the results given here.

Another disadvantage is that the technique is extremely exacting. Any extraneous movement by the subject renders the result valueless, and it is necessary for him to hold his breath while making the required movements, because even the act of breathing affects the results.

In order to ensure that no extraneous movement has occurred, no photographic records should be accepted unless at least two of the negatives coincide exactly

when superimposed. In a small series, the chances of an accidental movement combining with the true movement to give identical patterns on more than one occasion are so slight as to be negligible.

A series of six photographic records was made of each movement, and this was usually sufficient. However, some subjects found it difficult to maintain the necessary immobility and some series had to be repeated.

The subject repeated the required movement steadily from three to six times during the exposure. Therefore, each photograph is the equivalent of this number of repetitions of the "experiment," and the results were found to be reproducible at different times and under different conditions.

TABLE I

EQUIPMENT	REQUIREMENT
Screen	50 cm. by 50 cm.
Camera	1 M. distance
Lights	Two No. 1 Photofloods (wired in series) 0.5 M. apart; 1 M. distance
Aperture	f 5.6
Exposure	1.5 seconds
Film	Ortho. (Weston Meter 80) 32° Sch.

Photographic Technique.—The best results were obtained by using the equipment and setup as shown in Table I.

RESULTS

The purpose of this investigation was to determine whether movements performed with the teeth in contact were rotary in nature and whether the positions of the axes could be determined. The movements dealt with were (1) lateral movements to left and right and return to the position of centric occlusion, (2) retrusion from the position of centric occlusion and return, and (3) protrusion from the position of centric occlusion and return. The investigation, therefore, dealt with four different movements in each of 4 subjects, a total of sixteen movements in all. Each of these was found to be a movement of true rotation about a stationary axis. The number of axes located was too small for any general conclusions to be drawn, but some interesting facts emerged.

Lateral Movements.—These are much discussed movements and have long been thought to be rotary in nature. Definite experimental evidence to this effect has not, however, been produced, and the location of the supposed axes has been only theoretically deduced.

Simultaneous photographing of two screens could not be undertaken in the case of these movements, and it was necessary first to photograph a screen at a standard distance from the subject, then to move it to a second standard position on the frame in order to take the second series of photographs (Figs. 3 and 5). In each case, there was evidence of a rotary movement about a stationary axis.

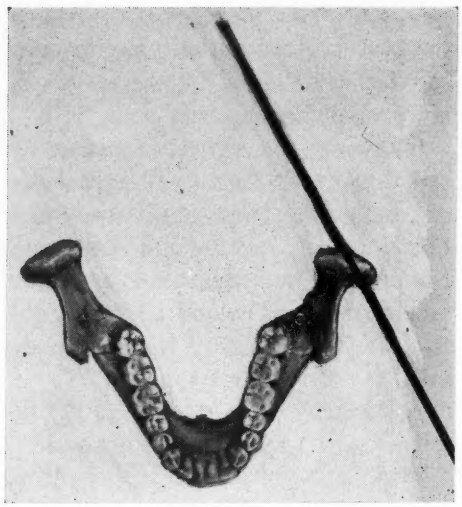

Fig. 9A.

Figs. 9*A*, 9*B*, and 9*C* show the average position of the eight axes located, all of which are treated in these diagrams as axes of lateral movements to the left.

In no case did an axis pass through the condyle. The distances from the lateral pole of the condyle averaged 4.65 cm.: six of the axes lay above and behind the condyles; two lay below and in front of them. The forward inclination was found to be far more marked than expected, all except two making an angle of less than 45 degrees to the occlusal plane. The axes made an average angle of 21 degrees to the sagittal plane.

The method of locating and recording the positions of the axes was as follows: (1) The stationary points were located on the appropriate photographs and the positions of these marked on the paper screens. (2) The apparatus was replaced

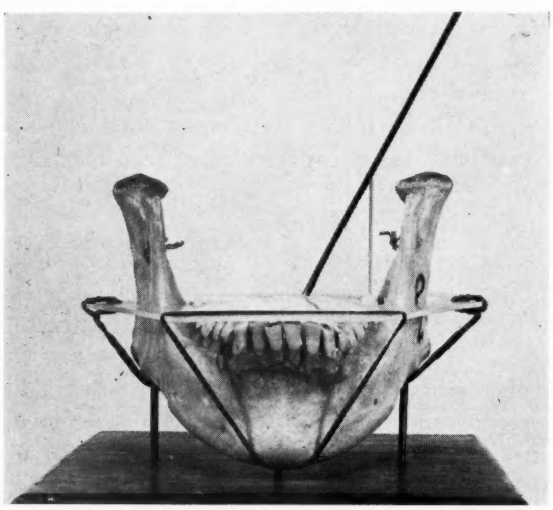

Fig. 9B.

on the subject, and a thin rod of balsawood was thrust through both screens at the marked points until it nearly touched the subject. (3) The subject was instructed to make the required movement, to ensure that the rod performed no movement other than rotation and did, therefore, lie along the axis. (4) The splint, complete with frames and screens, was next removed and placed on a cast of the subject's mandibular teeth. A permanent record was made by sliding a tube over the rod indicating the position of the axis and attaching this with plaster to a base carrying the cast.

Bennett movement: Once the position of the axis of a lateral movement has been visualized, the shift of the condyle on the working side can be better understood. This is the movement first demonstrated by Bennett[2] in 1908, but described 42 years earlier by Balkwill[3] (1866) and apparently observed 31 years before this by Bell[4] (1835).

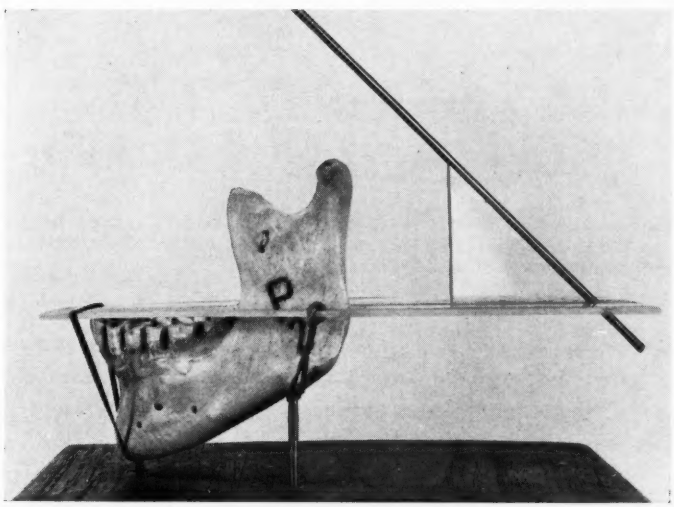

Fig. 9*C*.

Figs. 9*A*, 9*B*, and 9*C*.—A mandible with a rod showing the average position of the eight axes of lateral movements investigated. Right axes have been reversed and included with left.

During a lateral movement of the mandible, every point in it is traveling in its own circular orbit around an oblique axis. The condyle of the working side, being that part of the mandible closest to the axis, makes the least movement. Small though its movement is, however, it will nevertheless take place along an arc of a circle centered on the axis.

What happens to the condyle during a Bennett movement obviously depends upon its relation to the axis and upon the angulation of the axis.

In six of the lateral movements investigated, the axis lay above the condyle, and this moved downward, outward, and slightly backward. Of the two condyles with axes that passed in front of them, one moved almost horizontally inward, the other inward, upward, and backward.

That the condyle can be moved inward while the teeth move outward may, at first, be difficult to understand, but with the axis lying between them, this must happen just as the two ends of a seesaw travel in opposite directions.

In both of the joints that showed inward movement of the condyle, the axes lay far closer to the condyles than in the others; therefore, their movement was very small—22 per cent and 17 per cent of the movement in the incisor region—compared with an average movement on the part of the other condyles of 42 per cent of that in the incisor region.

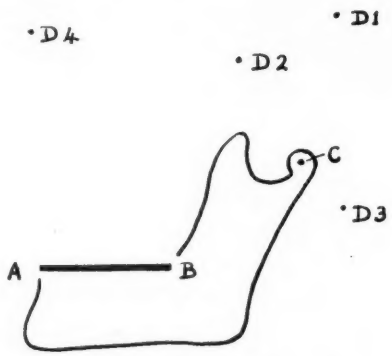

Fig. 10.—The positions of the retrusive axes of each subject related to the mean occlusal plane–condyle position of all four. *(AB)* occlusal plane; (C) intercondylar axis; *(D1, D2, D3,* and *D4)* retrusive axis of subjects A, B, C, and D, respectively.

Retrusion From the Position of Centric Occlusion and Return.—This retrocentric movement is not well known. A suggestion as to its nature has been previously advanced by the author as a result of theoretic studies,[5] and practical work by Posselt[6] has indicated its limits.

It was investigated by simultaneously photographing screens placed one on either side of the subject; Fig. 6 is typical of the rotary patterns obtained.

In each case, the movement was found to be rotary about a stationary transverse axis. In no case was the axis absolutely parallel to the intercondylar line (although it was very nearly so), and its relation to the intercondylar line was variable (Fig. 10). The greatest distance between the two, as measured on the surface of the face, was 9 cm.; the least distance was 2 cm.

The positions of the axes were recorded in a manner similar to that used for recording the lateral axis positions, except that because the screens were on either side of the patient's head, two balsawood rods had to be used. A stirrup placed over the subject's head ensured that these were properly aligned, and a face-bow was used to transfer the condyle positions to the permanent plaster record.

Protrusion From the Position of Centric Occlusion and Return.—In a normal subject, protrusive movement is made up of two parts (Fig. 11). The first part carries the lower incisors down the lingual surfaces of the upper incisors. The second part is performed with the incisal edges of upper and lower incisors in contact.

Both parts showed clearly in 2 subjects, but in the others, both of whom had lost upper central incisors, the first part was either diminished or absent. This was rather surprising, because I had thought that, in the absence of incisors, the cusps on the remaining teeth would have taken over the function of downward guidance of the mandible to produce, in some degree, the first part of the movement.

Each stage of the movement in all subjects was a rotary movement about a fixed axis, but there was marked variation not only in axis position but in axis symmetry also.

Thus, in no instance was an axis found that closely approached parallelism with the intercondylar line. All were roughly transverse but were set obliquely to one side or the other, indicating a movement that was not parallel to the sagittal plane but which deviated either to right or left.

Clinical examination of the subjects revealed that each did show deviation corresponding in direction to the obliqueness of the axis.

Fig. 12 shows the pattern produced by subject C, who had lost the upper central incisors. This is clearly a rotation pattern about a simple transverse axis, related to the second part of a normal movement, i.e., there is no downward guidance of the mandible. Fig. 13 shows part of the pattern produced by subject B and indicates the way it is produced. Parts only are shown because reduction of the whole pattern to a size suitable for printing would make the important angular lines too small to be seen. These angular patterns, pointing in opposite directions

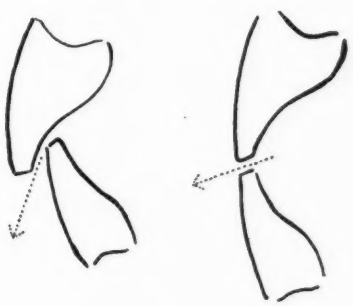

Fig. 11.—The two stages of a protrusive movement.

on opposite sides of the film, indicate rotation in opposite directions consecutively about two different axes. Both parts of the movement were present.

Subject A produced a similar pattern, but in subject D the axis of the first part of the movement showed an approach near to that of the second. This indicates a reduction in the downward guidance of the mandible during the first stage of protrusion which may be related to the loss of the subject's central incisors.

LOCATION OF THE AXES

These axes are more difficult to locate than the axes previously dealt with because they are often far removed from the screens.

Fig. 13, however, shows that as the patterns approach a line joining the axes, they become less and less angular until they approximate straight lines as they cross it. This makes it possible to establish roughly the position of the line joining the axes from a study of the photographs. If a line is now drawn on the photograph to represent this and is extended onto surrounding paper, a method of trial and error with compasses soon establishes the regions in which the axes must lie in order to produce the patterns seen in the photographs.

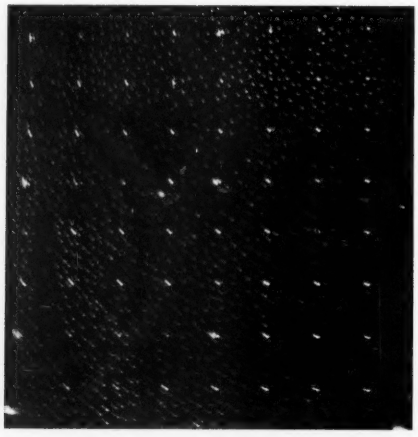

Fig. 12.—Protrusion from the position of centric occlusion (subject C).

This method can be checked with sufficient enlargement by drawing perpendiculars to equivalent portions of various individual patterns. These will converge upon the axis.

A further check is possible because the lengths of equivalent arcs of concentric circles are proportional to their distances from the center. Careful measurement of the lengths of various parts of the patterns and the distances between them enables the distance of the axis to be calculated.

These three methods, used together, give a reasonable assurance of accuracy. The circles around the axes in Fig. 14 show what is thought to be the outside limit of error in locating the axes of subject A.

It is interesting to note the similarity between the axis positions of subjects A (Fig. 14) and B (Fig. 15), both of whom possessed all of the incisors and a marked incisal guidance, compared with the axis positions of subjects C and D, who had suffered the loss of some incisors.

DISCUSSION

This investigation has produced a few new facts, but, in the main, it shows what can be accepted and what must be rejected from the work of previous investigators. Those who have maintained that mandibular movements made with the teeth in contact are rotary would appear to have been correct.

This is not surprising because it is a mechanical fact that surfaces cannot maintain constant contact with each other, unless they are made up either of (1) arcs of circles, each having a center on the same straight line, or (2) parallel straight lines. Truly parallel straight lines are practically unknown in Nature and are, in any case, only special instances of (1) in which the centers of the circles are at infinity.

It would, therefore, be expected that the movements that maintain a number of the surfaces of mandibular teeth in constant contact with similar surfaces of maxillary teeth would be rotary in nature. It would not occur to a mechanical engineer to doubt this for a moment, and this work has served to confirm that it does, in fact, apply in the cases investigated.

Gysi's[7] only error was in believing that the axes of the lateral movements are roughly vertical. Shaw[8] and Fischer[9] more accuately visualized the true situation. The positions of the axes of lateral movements, as theoretically deduced by them

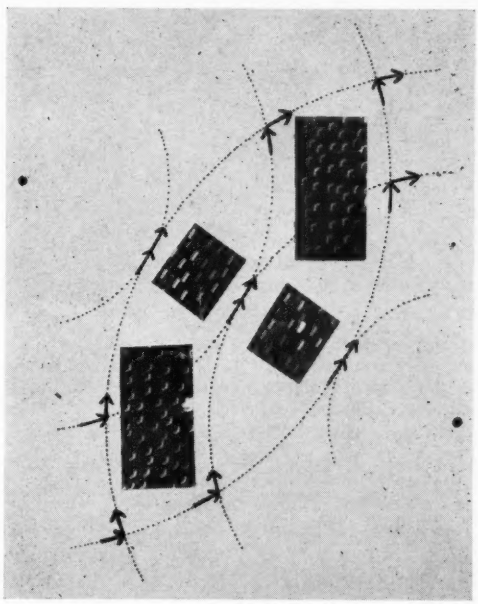

Fig. 13.—Protrusive movement of subject B. Reversed angular patterns produced in protrusion by some subjects. These indicate rotation in opposite directions consecutively about two different axes.

(Fig. 16), correspond with reasonable accuracy to the average position found in these investigations. That they do not correspond exactly does not mean that they were incorrect, for they lie well within the limits of the positions found in this investigation. Acknowledgment of the work of Shaw and Fisher is long overdue; it has passed practically unnoticed for more than 30 years.

Realization that these "gliding" or "closed" movements are rotary about fixed axes explains the way in which much of the confusion that exists on this subject has come about. To determine the position of an axis, it is necessary to locate at least two points on it. Knowledge of the position of one point tells us very little,

for innumerable axes could pass through this one point, thus allowing the mandible to rotate in any plane. Writers who have tried to describe mandibular movements by referring to a "center of rotation" have been attempting the impossible.

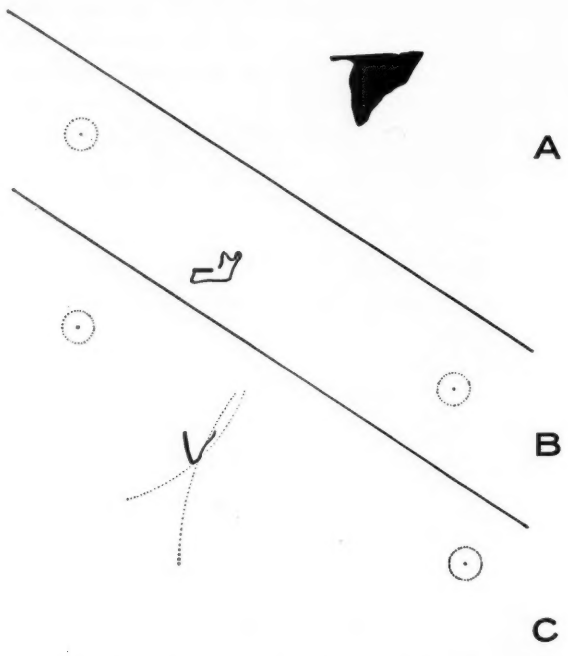

Fig. 14.—*A*, Photograph of section through a plaster model of an upper central incisor of subject A. *B*, Scale drawing to show the position of the axes of subject A in relation to the mandible. *C*, Geometric construction of enlarged central incisor in the position it would occupy in relation to the axes of subject A. Compare with *A*.

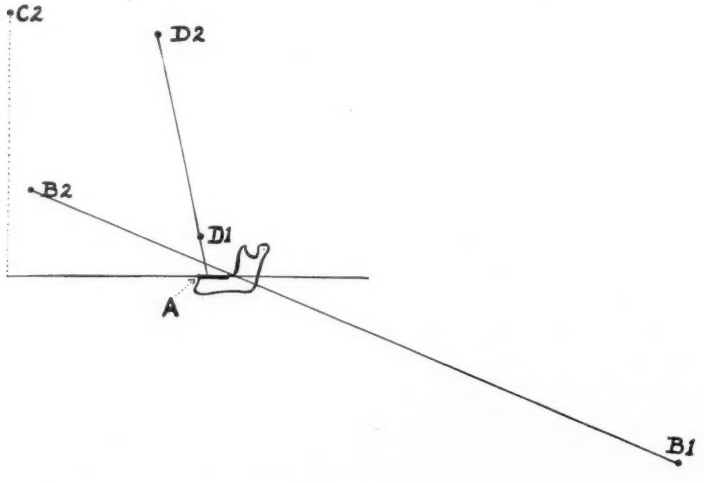

Fig. 15.—Positions of the axes of the protrusive movements of subjects B, C, and D.

It must be emphasized that there is nothing permanent about any of these axes. They are changed every time a patient's occlusion is altered, whether by the fitting of new dentures or by the insertion of a "high" filling, because their positions are determined by all the various factors that guide the mandible in its movement.

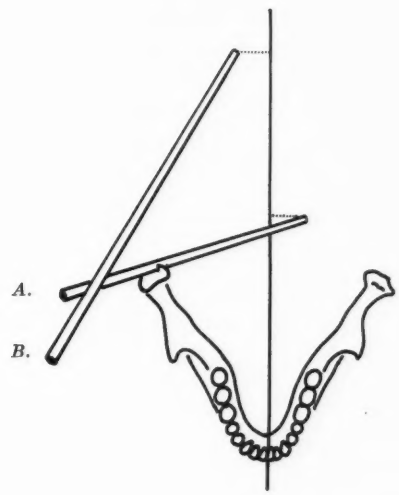

Fig. 16.—Positions of axes of lateral movements described by Shaw *(A)* and Fischer *(B)*. These are very similar to the positions found in this investigation.

It remains to investigate the axis positions of subjects with various types of occlusion. Those investigated so far were picked at random and were, apart from having reasonably complete dentitions, of no particular type. It is for this reason that no detailed descriptions of the subjects have been given. The investigation was undertaken to discover if there was a basic pattern of movement to be found in different types, and it was not greatly concerned with the variations that would affect the positions of the axes.

SUMMARY

Mandibular movements made with the teeth in contact were investigated in 4 different subjects by means of a new technique. These movements were lateral movements to right and left from the position of centric occlusion and return, retrusion from the position of centric occlusion and return, and protrusion from the position of centric occlusion and return.

Thus, sixteen different movements in all were investigated, or twenty, if the two stages of protrusion are considered separately.

All of these movements were found to be rotary about fixed axes, the positions of which were located and are described.

This work was carried out at Bristol University. My colleague there, D. C. Berry, M.D.S., Ph.D., and 2 of my students, Norman Thomas and Sam Harnaryan (now both qualified), have my gratitude and admiration for their patience during the long off-duty hours in which they acted as guinea pigs in these experiments. My sincere thanks are also due to D. Vero, L.D.S.R.C.S., for his great help with the photographic side of the work.

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HINGE AXES

Part III. Vertical and Sagittal Rotational Centers*

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THE MANDIBLE can do more than simply open and close. It is capable of protrusive and lateral movements, as well as movements which are combinations of protrusive, lateral, opening, and closing motion. For purposes of mathematical analysis, however, we consider only the extreme retrusive movements.

VERTICAL AXES

If the mandible of a patient were to be guided through its most retruded lateral movement path, one could theoretically locate a vertical center of rotation. There would be, actually, two vertical hinge axes—one for right lateral and one for left lateral motion (Fig. 1). These are called vertical hinge axes, because they lie in a plane which is perpendicular to the horizontal movements they govern.

SAGITTAL AXES

While we are observing the mandible making a pure lateral movement about one of its vertical axes, another phenomenon should be noted. Because of the slope of the fossa of the moving (nonworking or balancing) condyle, it must move downward as it moves forward. In other words, the moving condyle changes its "level" position with the working (stationary) condyle to a new position which is in front of and below the working condyle. Therefore, the moving condyle has made the mandible tilt about the stationary condyle. Because of this tilting, we postulate sagittal axes, one for each condyle (Fig. 2). No precise procedure for locating the sagittal rotational centers has been perfected, so the clinical significance of these axes remains open to question. An analysis of sagittal axis movement will not be presented.

ANALYSIS OF VERTICAL AXES

Usually, the vertical axes lie posterior to the transverse hinge axis. As such, it is theoretically impossible to duplicate movements about the vertical axis on an articulator which uses spheres as condyles (e.g., Hanau articulator and Gnathoscope). However, this potential inaccuracy is probably too minute to be of practical significance or clinical detectability.

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*Part I. The Transverse Hinge Axis, J. PROS. DEN. 10:436-440, 1960; Part II. Geometric Significance of the Transverse Axis, J. PROS. DEN. 10:631-636, 1960.

The analysis of the vertical axes will be approached from the aspect of what occurs if the distance between the vertical axes of the articulator does not coincide with the distance presented by the patient. The analysis considers the distance between the sphere centers of a Hanau articulator (108 mm.) and its variation from the average distance between the vertical axes as it has been measured on patients (120 mm.).

Fig. 1.—If the mandible were guided through a retruded lateral movement, it would rotate about a theoretic vertical center of rotation.

Terms with a subscript *1* refer to a 108 mm. distance between the vertical axes. The subscript *2* refers to an articulator which has been adjusted to the distance between the patient's vertical axes, 120 mm.

S_1 equals the distance from the center of the condylar sphere to the mesioincisal angle of the lower central tooth on the same side *(I)*. U equals half of the distance between the vertical axes. T equals the perpendicular to U that intersects S at I (Fig. 3). Therefore:

$U_1^2 + T_1^2 = S_1^2$
$U_1 = 54$ mm.
$54^2 + 9{,}500 = S_1^2$
$S_1 = \sqrt{12{,}416}$

$T_1 = T_2$ (Fig. 4)
$S_2 = \sqrt{13{,}100}$

$U_2^2 + T_2^2 = S_2^2$
$U_2 = 60$ mm.
$60^2 + T_2^2 = 13{,}100$
$T_2 = \sqrt{9{,}500}$

For movements about the vertical axis:

$$S_1^2 = (54 - x)^2 + (10\sqrt{95} + y)^2 = 12{,}416$$
$$S_2^2 = (60 - x)^2 + (10\sqrt{95} + y)^2 = 13{,}100$$

TABLE I

$x^2 + y^2$	x_1	y_1	x_2	y_2
1	0.8769	0.4807	0.8539	0.5204
4	1.7574	0.9547	1.7054	1.0448
9	2.6263	1.4500	2.5572	1.5687
16	3.5011	1.9345	3.4086	2.0932
25	4.3768	2.4173	4.2602	2.6174

The error of the articulator's movement is $x_1 - x_2$ and $y_2 - y_1$.

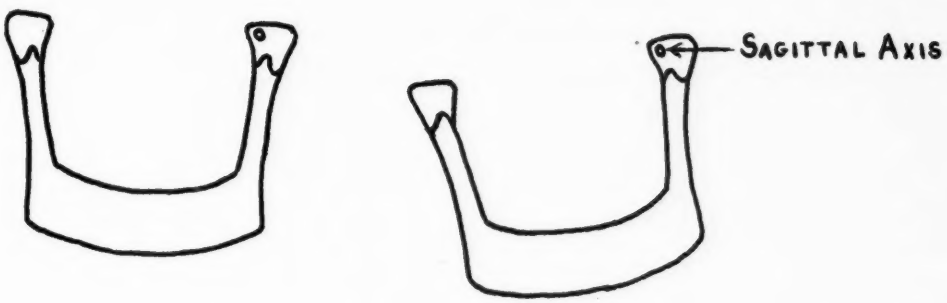

Fig. 2.—Because the mandible tilts about the stationary (working) condyle as the nonworking condyle moves down the slope of its fossa, we postulate sagittal rotational centers.

To determine the amount of lateral movement about the vertical axis in this case for analysis, let y equal the amount of forward and backward movement and x equal the amount of sideward movement (Fig. 5). Then, $x^2 + y^2 = z^2$. We shall substitute the numbers 1 through 5 for z (Table I).

The figures indicate that if the distance between the vertical axes of the articulator is insufficient, pure lateral movements of the articulator will correspond to lateral-protrusive movements in the patient's mouth. In other words, pure lateral movements on such an articulator would be too far forward to duplicate what the patient is capable of producing. Therefore, it is desirable to have an articulator on which the distance between the vertical axes is adjustable.

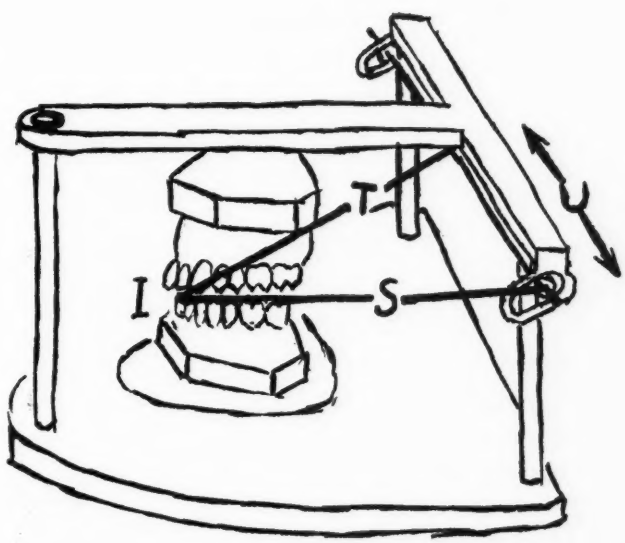

Fig. 3.—On this diagrammatic articulator, *U* represents one-half of the distance between the vertical rotational centers. *S* joins the vertical rotational center (at the height of the transverse hinge axis) to the mesioincisal angle of the lower central tooth on the same side *(I)*. *T* is the perpendicular bisector of the line joining the vertical axes at the transverse axis height and *T* intersects *S* at *I*.

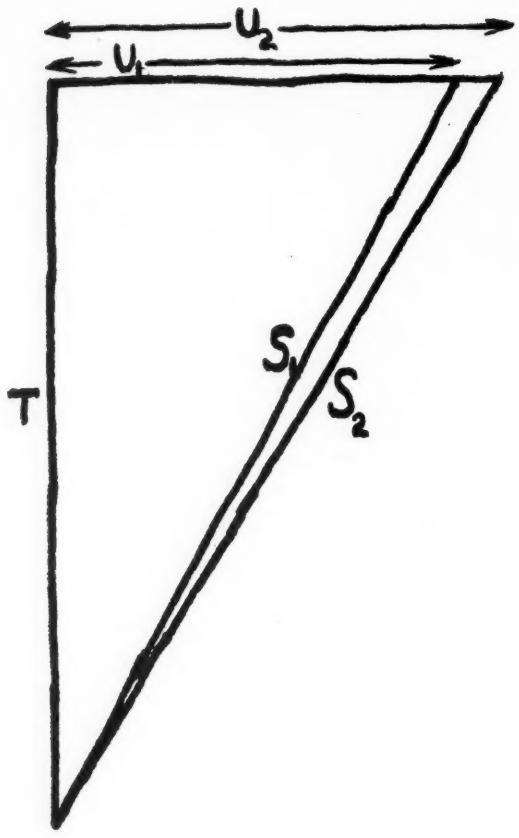

Fig. 4.—U_1 = 54 mm.; U_2 = 60 mm.; $S_2 = \sqrt{13,100}$. $T_1^2 + U_1^2 = S_1^2$. $T_1 = T_2$. $T_2^2 + U_2^2 = S_2^2$. Then $T_2 = \sqrt{9,500}$. Therefore, $S_1 = \sqrt{12,416}$.

CONCLUSIONS

1. It cannot be proved that the hinge axis position of the mandible is *the* proper terminal position, but we feel that this relationship is physiologically acceptable.

2. The ultimate purpose of the location of the transverse hinge axis is the verification of the maxillomandibular relationship. The mere recording of the hinge axis will not produce a superior restoration.

3. Not all interocclusal records are made while the mandible is in the hinge axis position. Therefore, it is necessary to verify the maxillomandibular cast relationship by using checking interocclusal records to ascertain that the mounting record was accurate.

4. We must use an articulator that is capable of being adapted to the patient's functional movements in order to use the transverse hinge axis and check the interocclusal records.

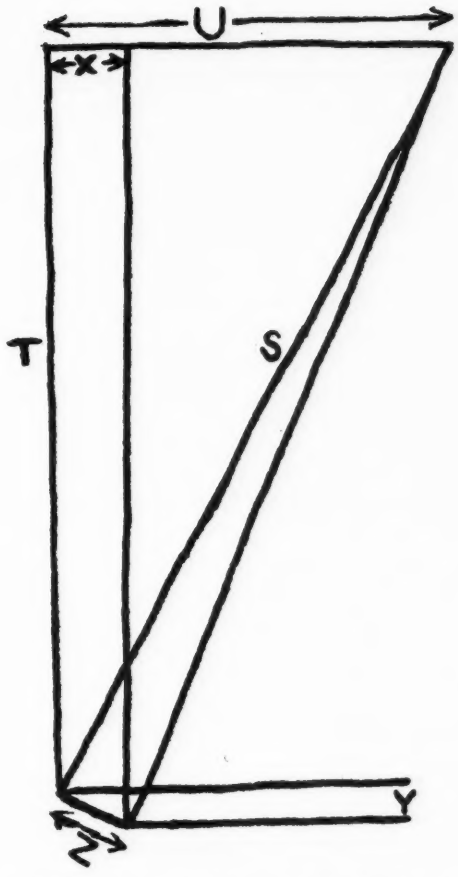

Fig. 5.—As the mandibular cast is moved to the side about a vertical rotational center, *I* (the mesioincisal angle of the mandibular central incisor) must move along path *z*. As *z* changes value from 1 to 2 to 3 to 4 to 5, a certain portion of its movement is anteroposterior *(y)* and a resultant movement portion is to the side *(x)*. The numerical values of x and y can be computed.

5. The use of nonhinge axis articulators when the vertical dimension of occlusion must be altered on the articulator will introduce a potential source of error.

6. An articulator on which the distance between the vertical rotational centers is adjustable is desirable in order to minimize occlusal errors.

7. It is difficult (perhaps impossible) to determine which magnitudes of error are of clinical significance and which are below clinical detection.

8. The use of a conventional face-bow may produce, in many instances, results which are close enough to being correct to warrant its use, but it would be impossible to determine if an error had been introduced during the mounting of the casts on the articulator. It would also be impossible to ascertain if the mounting interocclusal record were an accurate one, since the transverse hinge axis would not necessarily have been accurately located.

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SELECTION OF AN ARTICULATOR AND JAW REGISTRATIONS

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THE SELECTION OF AN ARTICULATOR and the use of jaw registrations are interrelated. The number and types of maxillomandibular registrations are governed largely by the instrument which is selected by the dentist. Maintaining and duplicating the accuracy of such records after the transfer to an instrument are limited by the adaptability of the instrument to the records. Most articulators impose other limitations beyond these conditions.

The analysis of the selection of an articulator for complete denture construction may be resolved into three approaches: (1) the general function of an articulator, (2) the construction of the instrument, and (3) the errors which may result from the function and the construction of the device.

FUNCTION OF AN ARTICULATOR

An adjustable articulator is often thought to establish reciprocal relations of the occlusal surfaces and the relative positions of the denture teeth with the movement of the mandible. Actually, most instruments duplicate up to three selected eccentric positions of the mandible by making them correspond to the initial and end points of paths, one or all of which may have been recorded. An opening component is usually incorporated in these selected protruded and right and left lateral positions.

CONSTRUCTION OF ARTICULATORS

Usually, articulators are designed with three mechanically adjustable guides which are connected directly, or indirectly, through the attachment of casts. Most instruments utilize a solid or a "broken" shaft axis perpendicular to the opening and closing plane of motion of the device. Usually, this axis connects the two condylar guidance mechanisms.

Instruments differ, however, in the location of the guidance mechanisms and in the manner of attachment of these guidances. The guidances may be in the condylar regions, in the incisal region, concentric with a spherical center, or in an otherwise arbitrary location. The condylar guidances may be attached to the lower, immovable member or to the upper, movable member of the instrument (Fig.

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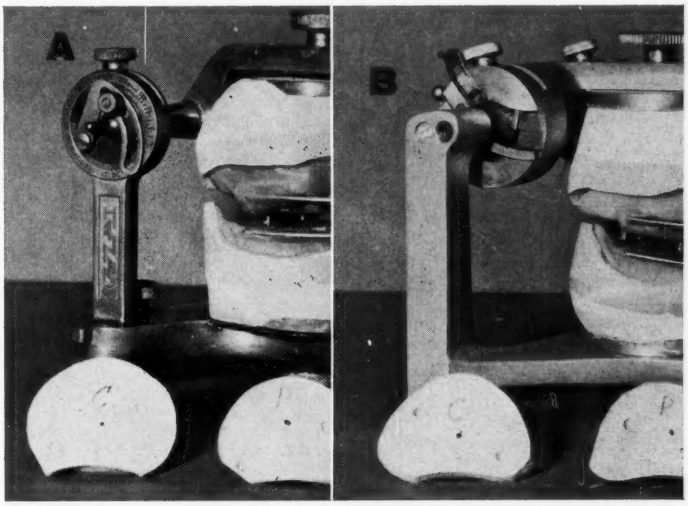

Fig. 1.—*A*, The condylar guide is attached to the lower member of the instrument. *B*, The arcon guide is attached to the upper movable member of the instrument. (The term "arcon" is from Bergström, Gunnar: On the Reproduction of Dental Articulation by Means of Articulators, A Kinematic Investigation, Acta odont. scandinav. 9:suppl. 4, 1950.)

1). Each guidance varies as to the method and number of adjustments, the interrelation or independence of the adjustments, and the adjustments for each individual movement (Fig. 2).

ERRORS IN ARTICULATORS

Since it is possible to adapt an instrument only to records which have been secured from a patient, the dentist often transfers certain parameters to the machine. An example of such arbitrary values are the selection and location of an axis of the mandible which is to correspond to the shaft axis of an instrument. Further, it is possible to err either in the determination of the location of the selected axis because of conditions imposed on the mandible or in the interpretation by the dentist of the accuracy of the location of the axis.

Any axis of the mandible may be made to conform to a protrusive movement in plane motion, i.e., when all points in the mandible move in parallel planes (Fig. 3). However, such a protrusive movement may rarely exist in actuality.

Errors which result from opening movements of the articulator can be reduced by a shaft axis that represents the axis of the mandible which has the least movement with respect to the skull during the closing movements. Such an axis may be found by a hinge-bow.

Errors also develop when one opening and closing axis with its related guides is made to conform to more than one motion. These errors are initiated when one set of adjustments is made on the guides of an instrument by one record, such as the record of protrusive movement, and these same guides are used for other movements.

GUIDE PATHS

In general, the establishment of guide paths on an articulator by locating end points and then expecting the machine to perform motions identical to those of the mandible is erroneous. Such guide paths are established with interocclusal or other records which are secured from the patient and transferred to the instrument.

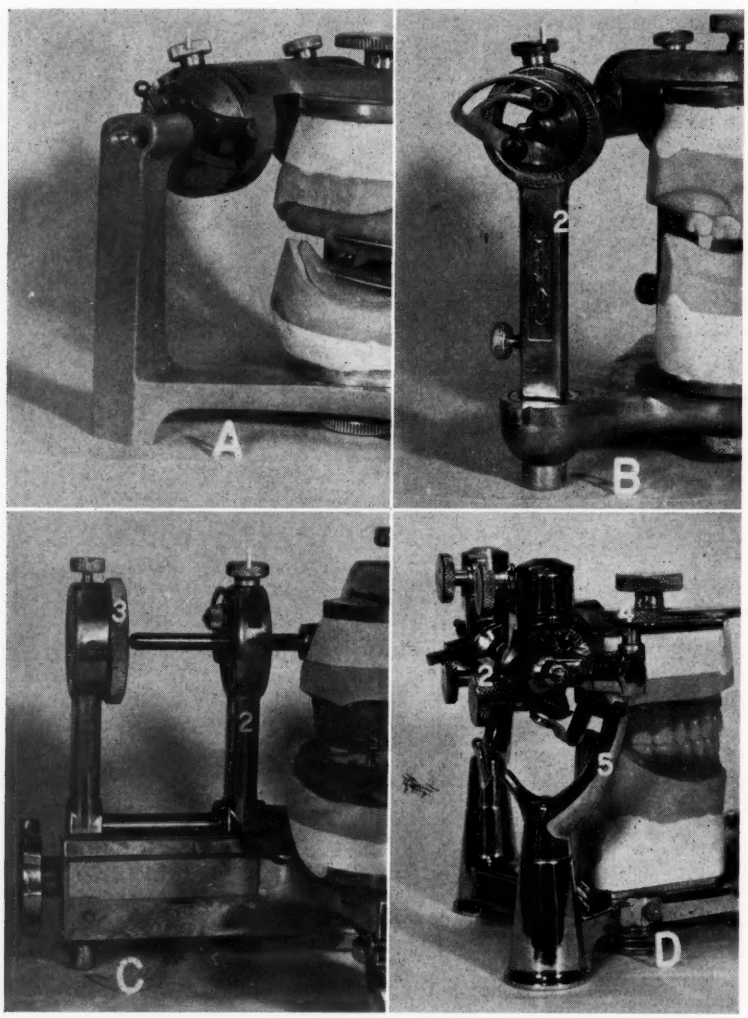

Fig. 2.—Variations exist in the number of adjustments in the region of the condylar and arcon guides. *A*, The arcon guide with one adjustment. *B*, The condylar guide with two adjustments. *C*, The condylar guide with three adjustments. *D*, The arcon guide with four adjustments; adjustment *3* is at the incisal table.

While the initial and terminal positions of the articulator may coincide with the same positions of the mandible, the instrument may perform movements quite different from the mandible at the many intermediary positions. This condition

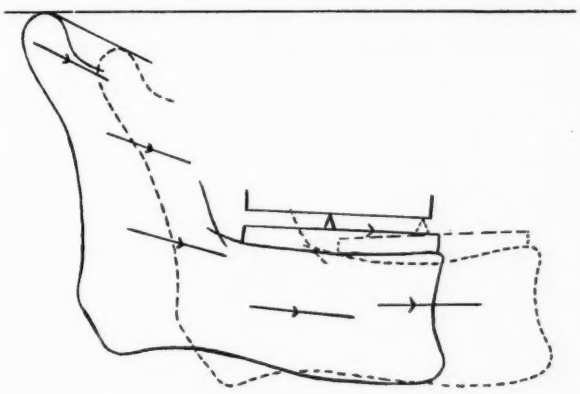

Fig. 3.—The path of any axis can be used to describe plane motion of the mandible.

exists particularly when the guide paths are attached to the lower member of the instrument. If the guide paths are attached to the upper member of the instrument, fewer factors influence the setting of these guide paths.[1] Theoretically, more accurate reproductions of mandibular movements are obtainable by such an arrangement, since the relationship between the occlusal plane and the guide paths remains constant (Fig. 4).

The correspondence of the curves of the guide paths of the articulator to the paths of the condyles also influences the error developed in an articulator.

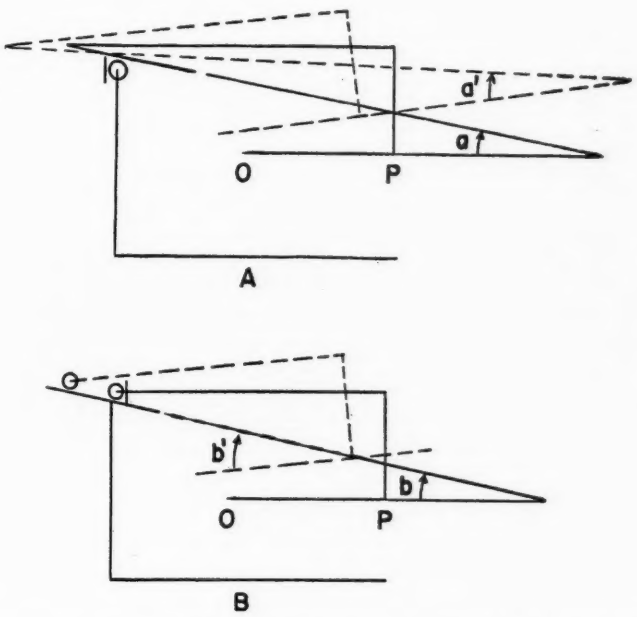

Fig. 4.—The relation of the occlusal plane to the manner of attachment of the arcon and the condylar guides on articulators. *A*, Angles *a* and *a'* are equal in a protrusive and opening movement of an arcon guide; *OP* designates the occlusal plane. *B*, Angle *b'* is greater than angle *b* in a protrusive and opening movement of a condylar guide.

Individual curved paths are sometimes incorporated in the guide mechanisms of articulators in an attempt to simulate certain registrations which are secured from the patient.

Consideration should be given to the spacing of the guide mechanisms to coincide with the distance between the condyles and the control of the shift of the mandible bodily. Fig. 5 illustrates the variation in the angulation of a tracing made in the region of the condyle, because the position of the stylus does not coincide with the location of the condyle. The only instance in which the angulation of the tracing is equal to that of the condyle path occurs when the angulations of both condyle paths are identical.

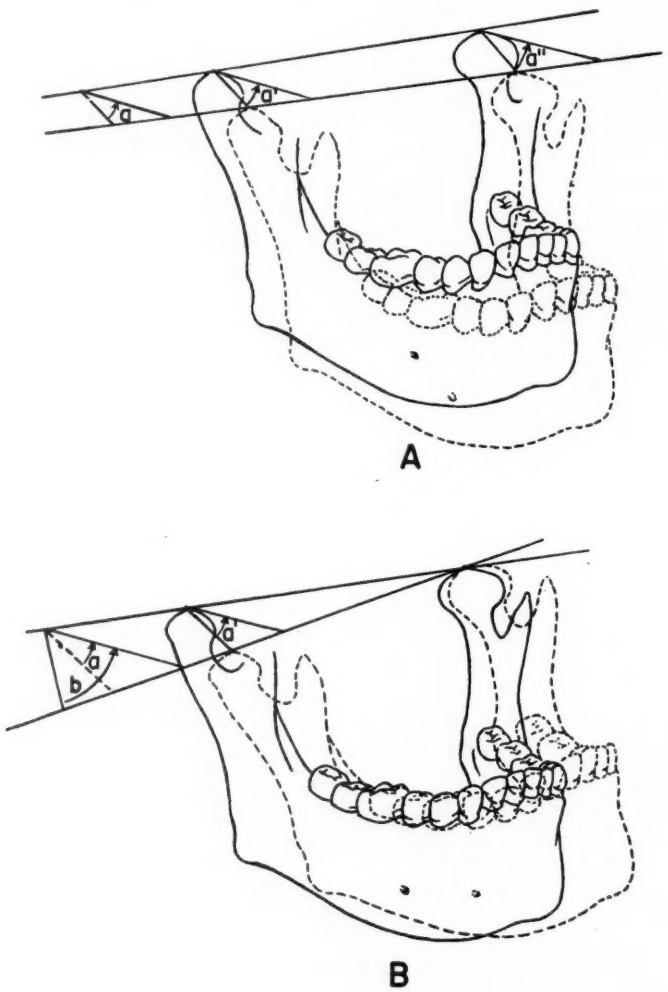

Fig. 5.—A difference in tracing angulation is due to its location outside the condyle. *A*, Angle *a* of the tracing and angle *a'* of the condyle contact path are not the same in a protrusive movement when the condyle paths *a'* and *a''* are of different inclinations. *B*, Angle *b* of the lateral tracing is greater than angle *a* of the protrusive tracing.

Fig. 6 shows the influence of the difference in joint distances of the skull and the articulator on the condylar guide inclination. An error is always introduced when the distance between the "joints" of the instrument is not equal to the distance between the condyles.

Articulator guides which control several movements introduce an uncontrolled lateral shift or Bennett movement. The usual design is to make both the magnitude and direction of the lateral shift vary linearly with the setting of the guide and the amount of lateral movement (Fig. 7). However, additional factors usually influence the lateral shift, such as the inclination of the condylar guide, the distance between the condylar guides, and interference from holding the articulator in such a way that the shift cannot occur. Such an uncontrolled shift can occur also during a protrusive movement.

If separate and calibrated guides are used for each of the protruded and the right and left lateral positions on an instrument, the distance between the joints becomes insignificant and the lateral shift is more rigidly controlled. The guides on the instrument are set to each position to conform to the interocclusal records as secured from the patient (Fig. 8).

JAW REGISTRATIONS

Most articulators are limited in various degrees in their adaptability to *all* positions of the mandible in relation to the maxillae. Many instruments can duplicate the initial and terminal positions as recorded on the patient. However, this provides no assurance that all or most of the intermediary positions of the mandible can be reproduced.

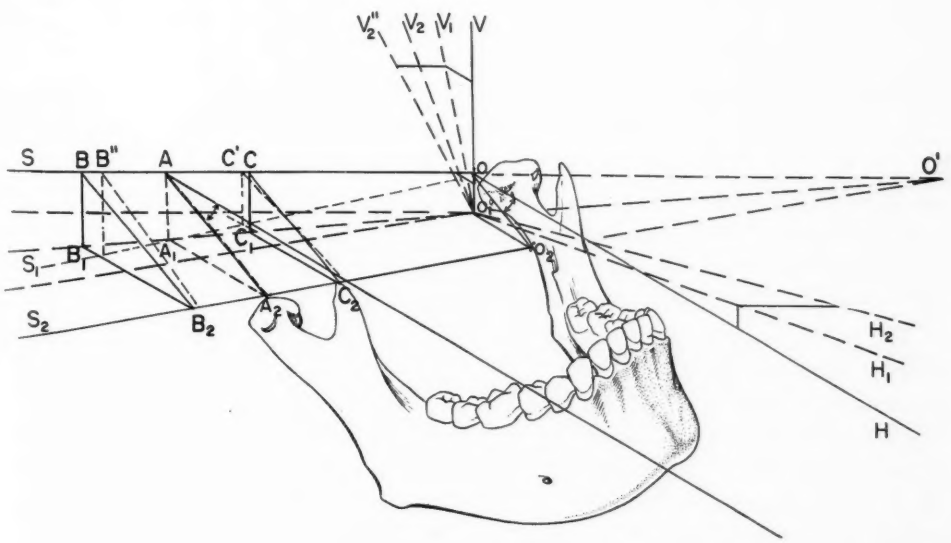

Fig. 6.—The difference in the path inclinations of a point in protrusive and lateral movement is influenced by the joint distance.[1]

A centric relation record made at a given vertical opening is imperative. Such a record can be an interocclusal record made with or without a tracing or tracings. It is desirable to check this centric relation record repeatedly and, whenever possible, by both methods.

Protruded and lateral maxillomandibular records in which the vertical components of these mandibular positions have been incorporated are of value. This is

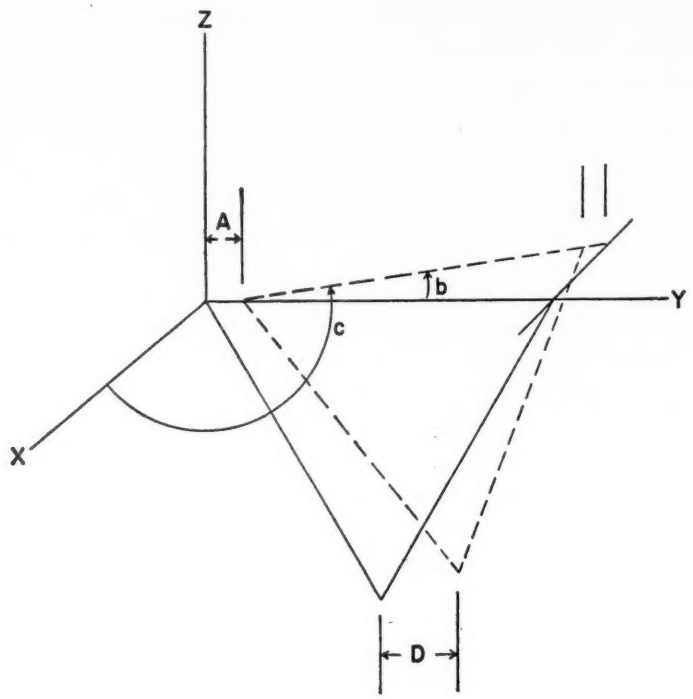

Fig. 7.—The magnitude of the Bennett movement *(A)* is influenced by angles *b* and *c* and by the magnitude of lateral movement *(D)*.

particularly true if a tripod or a shaft axis instrument (acting as a tripod) is used without regard for the opening and closing axis of the mandible. These records make it possible to adjust the instrument to these positions, but they do not duplicate all intermediary positions of the mandible to the maxillae.

A transfer of the jaw relationship by means of a hinge axis record is of value when a shaft axis instrument other than a tripod is used. Although this axis may not be a fixed axis in respect to the mandible, it is the axis of least movement for a selected movement of the mandible.[2] In complete denture construction, other factors may influence the dentist in locating this axis. These are the difficulty of stabilizing the record base on resilient tissues and the influence of and interference by the recording apparatus upon mandibular position and movement. Nevertheless, if the recording apparatus can be stabilized, and if it imposes little weight on the mandible, a transfer by the hinge axis record is the method of choice.

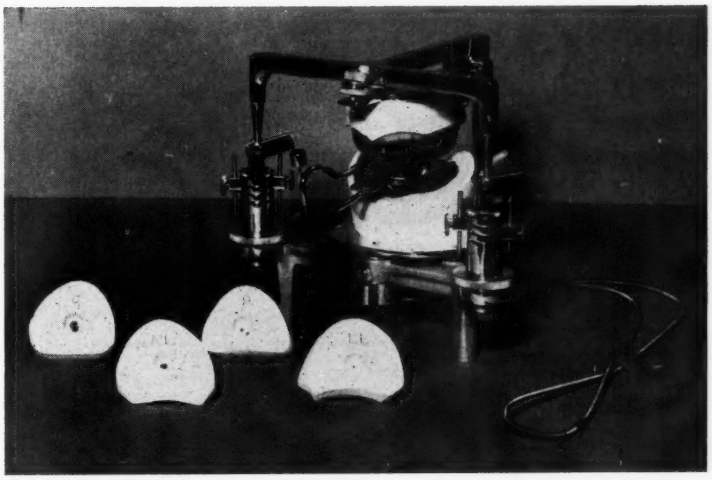

Fig. 8.—A tripod type instrument in which the joint distance is insignificant and the lateral shift is controlled (Stansbery's technique).

The axis-orbital plane should be used as a reference plane in the mounting procedure. A reference plane includes the selected hinge axis and the orbital point. The convenience in mounting and the more accurate positioning of the anterior teeth which result from the use of the axis-orbital plane make it valuable.

CONCLUSIONS

1. A centric relation record and other selected eccentric records are essential.
2. Most instruments can duplicate only selected relations of the mandible and cannot duplicate all intermediary relations.
3. The selected mandibular relations should consist of records of the protruded and the right and left lateral maxillomandibular positions for adjusting instruments which are used as a tripod.
4. A hinge axis record and transfer is suggested when a shaft axis instrument which is not acting as a tripod is used.
5. The axis-orbital reference plane for orienting the casts on a shaft axis instrument is recommended.
6. The condylar guides should be attached to the upper member of articulators.
7. An error is introduced when the distance between the joint mechanisms of a fixed shaft articulator is not equal to that between the condyles.
8. All guides of an articulator should be independently adjustable.

SUMMARY

No machine is capable of reproducing muscle synergy and proprioception. Articulators can be adjusted to the positional records as secured from the patient, but they can only approximate mandibular movements.

Many of the errors incorporated in articulators result from the attempts to use one set of guides for all of the selected articulator movements. Insufficient range of adjustment is allowed in these instruments for the duplication of the mandibular movements. Even when sufficient adjustments are included in the articulator, each adjustment cannot be set by direct, independent measurements of the corresponding value in the head. Instead, articulators are set by indirect measurements which often are composite indications of several dimensions. Hence, the significance of the theoretically increased accuracy of the more adjustable instruments is questionable. The optimal number of adjustments which should be incorporated in an articulator has not yet been determined by clinical evaluation.

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TROUBLE SHOOTING IN COMPLETE DENTURE PROSTHESIS

Part VI. Factors of Oral Hygiene, Chemicotoxicity, Nutrition, Allergy, and Conductivity*

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PERIODONTISTS RIGHTFULLY STRESS ORAL HYGIENE as essential for both prevention and treatment of inflammatory conditions of the oral mucous membranes. In some instances, the diagnostic clues indicate that the septic condition of the dentures is entirely responsible for the inflammatory condition of the oral mucosa.

INFLAMMATORY CONDITIONS CAUSED BY LACK OF ORAL HYGIENE

The degree of guilt of lack of oral hygiene in denture-sore mouth is difficult to determine. From a clinical point of view, however, some failures in denture prosthesis are caused by the patients' disregard of the elementary rules of oral hygiene. This important phase of denture care cannot be overemphasized. The putrefactive material, glandular secretions, desquamative epithelium, and multitude of microorganisms from the oral cavity that accumulate around filthy dentures may even cause some general diseases. Oral hygiene is just as important for denture patients as it is in the prevention of dental decay.

Rough surfaces of dentures, as well as surface porosity of denture-base materials, provide a favorable site for harboring bacteria of the oral flora and promoting their multiplication. Great amounts of tartar are observed frequently on the lingual flange of lower dentures that have not been polished properly.

Because good habits of oral hygiene are an important aid in preventive dentistry, it is our duty to do all we can to inculcate and encourage them. However, our approach must suit the delicacy of the subject. Such discussions with patients must be carefully planned and gently executed. Abrupt statements about the uncleanliness of dentures are both tactless and painfully offensive. It is most important to induce a receptive mood in the patient. We might relate experiences with patients whose skin was so delicate and fine that mere contact with certain substances gave rise to erythemas and eczemas on the hands, whereas these substances are perfectly harmless to most other people. Turning then to the oral mucosa, we point out that it is similarly delicate and extremely sensitive to the slightest irritation. Because of this, only extra care will do. Ordinary standards of hygiene are insufficient. Then, we go on to tell the patient how to achieve satisfactory oral hygiene.

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*Part I, J. PROS. DEN. 9:978-987, 1959; Part II, J. PROS. DEN. 10:42-46, 1960; Part III, J. PROS. DEN. 10:263-268, 1960; Part IV, J. PROS. DEN. 10:490-495, 1960; Part V, J. PROS. DEN. 10:682 687, 1960.

CHEMICOTOXIC INJURIES TO THE ORAL MUCOSA

Many agents are capable of producing inflammatory conditions of the oral cavity though acting through different channels. The best examples are mucosal inflammations caused by drugs and drug eruptions on the skin. Skin eruptions resulting from penicillin injections are well known. Phenolphthalein, often used as a purgative and laxative, may be the responsible agent for lesions on the oral mucosa. Other inflammatory conditions of the oral mucosa caused by drug poisoning are mercurial stomatitis, stomatitis caused by lead poisoning, and bismuth stomatitis.

The prosthodontist's chief concern are poisonous substances in denture-base materials. The cumulative effect of the absorption of these substances or their contact with the oral mucosa may cause mucosal lesions of various types. When vulcanite was used as a denture-base material, many lesions of the oral mucosa, probably traumatic in nature, were ascribed to toxic substances contained in the material itself. Thus, free sulfur and vermilion (the coloring matter of vulcanite) were considered the main toxic substances. However, inflammatory conditions of the oral mucosa were reported from the use of materials other than vulcanite. Such reports were particularly frequent soon after the introduction of these materials. Inexperience in handling new materials and improper curing might have been the reasons for their toxicity. Tests were conducted with methyl methacrylate by applying the pure monomer to the skin. Positive reactions were obtained in about half of the subjects. In similar tests with the completely polymerized product, however, there were no reactions of toxicity observed. "Reliners" occasionally cause toxic effects to be manifested on the oral mucosa.[1,2]

Chemicotoxic injuries to the oral mucosa occur only in rare instances. But, because this form of injury is within the realm of possibility, it should be borne in mind in diagnosis of inflammatory conditions of the oral mucous membranes. In addition, a careful history of the patient's life, background, subjective symptoms, and environment is indispensable.

POOR NUTRITION AND AVITAMINOSIS

The dentist must be alert to possible nutritional causative factors in inflammatory conditions of the oral mucosa. If unrecognized, these conditions will invariably lead to mutilation of the dentures, because the main source of the trouble receives no attention. Vitamin deficiencies are widespread even in countries with an abundance of food. Although people may eat plentifully, they may not be properly and adequately nourished.

The oral mucosa may simulate symptoms of traumatic occlusion when, in reality, the patient is suffering from a severe case of avitaminosis. In addition, the denture patient may require a greater than normal vitamin intake because of advanced age, with its frequent impairment of gastrointestinal function. Also, the loss of the natural dentition and its replacement by dentures may contribute to the deficiency. Yet, dentists should guard against becoming vitamin fadists. Vitamin therapy should be limited to vitamin deficiency syndromes only. Thus, the burning mouth, burning tongue syndrome in women during the menopausal stage may, in

a great measure, be due to a vitamin deficiency. On the other hand, some women in the menopausal and postmenopausal states really starve themselves without being aware of it. Other women afflicted with the burning mouth syndrome may not suffer from avitaminosis. Therefore, a thorough history and a thoughtful evaluation of diagnostic clues relating to vitamin deficiencies are essential before specific vitamin therapy is administered.

Various types of nutritional deficiencies are observed in the oral cavity in the form of stomatitis. These vary in degree from a mild redness of the mucosa to severe inflammatory conditions with all their signs and symptoms. Treatment of nutritional deficiencies depends upon the etiological factors. In most instances, treatment consists of a rational change in the diet and administration of the deficient vitamins.

ALLERGIC REACTIONS TO DENTURE-BASE MATERIALS

Many of the diseases formerly classified as allergies are of psychosomatic origin. In the treatment of asthma, hay fever, and eczema, it has become very difficult to separate the psychosomatic component from the allergic manifestations. The patch test for the skin and the mucosal contact test for the mucous membrane may suggest manifestations of an allergic character to the allergist. However, the same symptoms may be treated successfully by the psychiatrist by means of psychotherapeutic procedures.

In prosthodontics, few lesions can be labeled as typical allergies. It is only after eliminating all other etiological factors that we may suspect allergic factors. Indeed, the greater the experience and competence in diagnosis of diseases of the oral mucous membranes, the less the dentist is inclined to overrate the importance of allergy. Many prosthodontists feel that allergy covers a multitude of disturbances. Whenever it is difficult to make a diagnosis, it is very convenient to pin the trouble on an allergy. Frequently, it is not an allergy, but an incorrect centric jaw relation registration or an incorrect centric occlusion that is responsible for inflammatory conditions of the oral mucosa.

However, since allergic conditions do exist, the dentist should bear them in mind. Most of the standardized acrylic resin materials that are now used as denture-base materials may be considered perfectly safe if they are properly cured.

Inflammatory conditions of the mucosa, after use of certain toothpastes or denture cleansers, need not be considered allergic manifestations. In most instances, they are irritations of chemicotoxic origin.

CONDUCTIVITY OF THE DENTURE

Poor heat conductivity of the denture-base material may have an injurious effect upon the oral mucosa, but its importance should not be overestimated. We are frequently confronted with an inflammatory condition of the maxillary vault which presents an ugly appearance. The mucosa is crimson red and flabby in consistency. The patients usually do not experience any pain but are frightened by the appearance and may even become afflicted with cancerophobia. The same condition may prevail on the mandibular ridge, but in a milder form.

The exact etiological factors of this condition have not been established. The low thermal conductivity of the denture-base material may, to some degree, be responsible. The accumulation of heat under base materials may change the environmental conditions of the mucosa in an unnatural direction. However, many causative factors may participate simultaneously in the formation of this syndrome.

In some instances, successive changes of denture materials will alleviate the situation. No change in a denture-base material should be contemplated, however, unless it is certain that no other cause for the trouble can be found. When the denture-base material is changed, the patient should not be given too much encouragement. The emphasis should be placed on the reassurance that the redness of the mucosa, and any smarting sensation associated with it, does not carry any serious implications. I have witnessed many cases of red mucosa which persisted for many years without any ill effects whatsoever. However, before embarking on positive patient reassurance, we must be sure of the diagnosis. Where such assurance is lacking, consultation with a competent specialist is imperative. This will provide the dentist with the emotional support he needs for the effective treatment of his patient.

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REMOVABLE PARTIAL DENTURES

THE RATIONALE OF PARTIAL DENTURE CHOICE

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CHOOSING ONE OF THE POSSIBLE PROCEDURES for restoring the partially edentulous dental arch involves borderline decisions. Often, a complexity of oral conditions may exist, regarding which decisions ultimately must be made. In addition, partial denture design is complicated by the many possible combinations of the remaining teeth, so the making of a choice in restorative procedure may become disconcerting.

Prosthodontists have been tolerant of a poorly organized approach to this problem. Sometimes, little logic is used in arriving at a selection of prosthetic treatment for the varied semiedentulous situations. The resulting uncertainty often has caused dentists to delegate responsibility in designing the removable partial denture.

With caries control methods not having gained nationwide application, many broken dental arches will continue to need partial denture service. Indirectly, modern periodontic treatment has also been responsible for a steadily increasing demand for partial denture service. Many periodontally involved teeth are returned to a condition of health for patients already partially edentulous. Formerly, most of these teeth would have been extracted. These patients will have been told, *and rightly,* that the missing teeth must be *replaced at once* to protect the results already achieved by occlusal equilibration and periodontal therapy.

Thus, a future load of increasing need for partial dentures is confronting dentistry. Much of this required service can be supplied only *by the general practitioner.* This prospect indicates an urgent need for clarification of at least those partially edentulous situations which are found repeatedly in clinical dentistry. The indications and contraindications for various restorative procedures should be better correlated with the principles of removable partial denture design so as to be successfully applied by a dentist with less than specialist training in prosthodontics.

Read before the Academy of Denture Prosthetics, Louisville, Ky.

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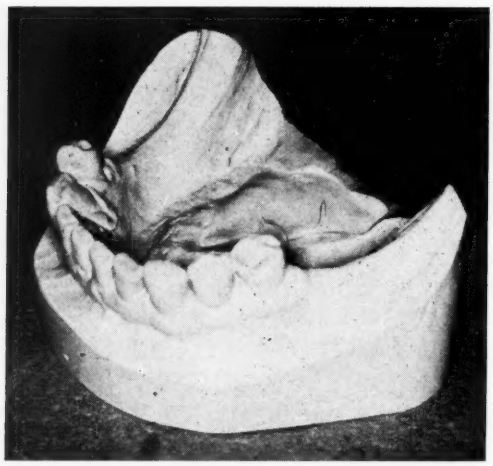
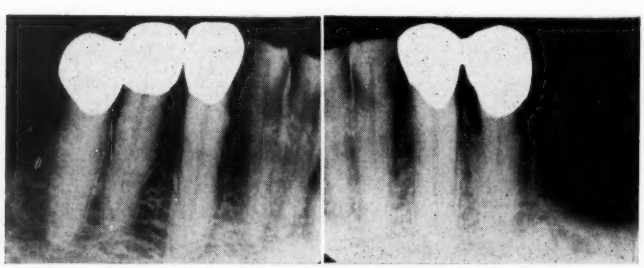


Fig. 1*A*.—The partially edentulous situation which occurs with the greatest frequency is a mandibular class I condition.

FACTORS AFFECTING THE CHOICE OF PROSTHODONTIC TREATMENT

Classification in removable partial denture prosthesis should be specifically related to oral conditions. In the past, classification has been restricted only to the designation of vacant spaces in the dental arch. Actually, the size of edentulous spaces, even the location of remaining teeth, are secondary in diagnostic significance to the condition of the supportive structures. Other factors[1-4] have much more important bearing on what should be done prosthetically than the number, or even the location, of the remaining teeth. Of these factors, only the most important will be discussed.

Bone Maintenance Potential.—The capability of the patient to replace bone elements as rapidly as they are used is at the top of the list of desirable conditions. A physical examination which accurately evaluates the systemic condition may be necessary. However, good roentgenograms of the complete alveolar process usually will give a dependable index as to the patient's potential metabolic function as it affects bone maintenance.



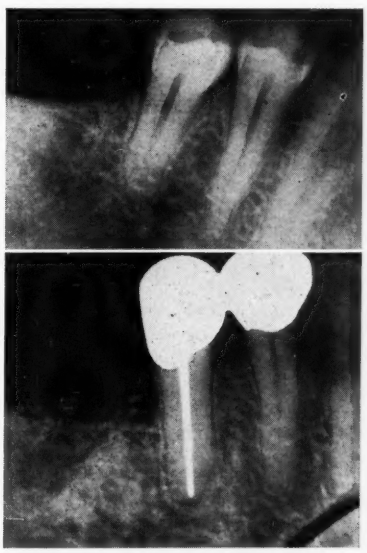
B. *C.*

Fig. 1, *B* and *C*.—The bone maintenance is exceptionally good, considering the long service of the abutments and that the patient is nearly 70 years of age. Note the extreme atrophy (particularly in *A*,) in the posterior edentulous ridges.

The ability of the patient to tolerate prosthetically induced stress loads is directly related to his past record of alveolar bone maintenance in areas of hyperfunction. Such dependable index regions of alveolar bone exist around teeth that have served as abutments, inclined teeth, teeth adjacent to edentulous spaces and which are in occlusion, and teeth in traumatic occlusion. The exception to this rule is in the patient who has undergone physical changes which would interfere with his metabolic function. Any restoration of masticatory function, to be more than temporary, *must be attuned to the patient's evident ability to maintain alveolar bone.*

Previous Cervical Bone Loss.—Even when a morbid metabolic function has been returned to a normal level, some permanent bone loss may have occurred. The extent of prosthetic load which may be safely allocated is then affected. The occlusal stresses are magnified since the *extra-alveolar* segment of the abutment tooth has been lengthened by cervical bone loss. This is not to say that such teeth cannot function as abutment teeth, but it does materially affect the type of mouth preparation and the choice of restoration.

A.



B.

Fig. 2.—*A*, The lower left bicuspids have carried a very heavy occlusal load for many years. The patient is a vigorous, healthy man, about 42, able to exert exceptionally heavy biting forces. Note the excellent bone maintenance. In spite of this, a carefully constructed class II partial denture base carrying the molars showed a loss of stability within a short time. This is a common example that even when there is normal alveolar bone there may be atrophy in the unused sector of the same dental arch. *B*, The boundary tooth in a class I situation may need extensive restoration, or often it may not be able to serve alone as an abutment for the needed extension restoration, but by union with an adjacent tooth adequate abutment service can be provided.

Abutment Root Form, Length, and Stability.—The next most critical influence in recovery of the patient's dental facilities is the anatomic condition of the prospective abutment teeth. The length of the root determines the *intra-alveolar* support which can counteract the extra-alveolar stress or the work portion of the lever arm.

Form of the abutment root is important, because *if the root tapers sharply,* any previous cervical loss of bone is doubly significant. The amount of the remaining alveolar wall which supports the abutment load is reduced rapidly when the root is steeply tapered. Such roots can be used for abutment support only when definite measures have been taken to supplement the abutment function. The splinting of two or more adjacent teeth is the most dependable solution in this situation.

Extent of Periodontal Involvement.—The degree of lateral mobility of an abutment tooth is of lesser clinical significance. Unless there also has been serious periodontal damage, the tooth will recover its previous firmness. However, this recovery depends upon the alleviation of the local predisposing conditions which produced the excess mobility in the first place.

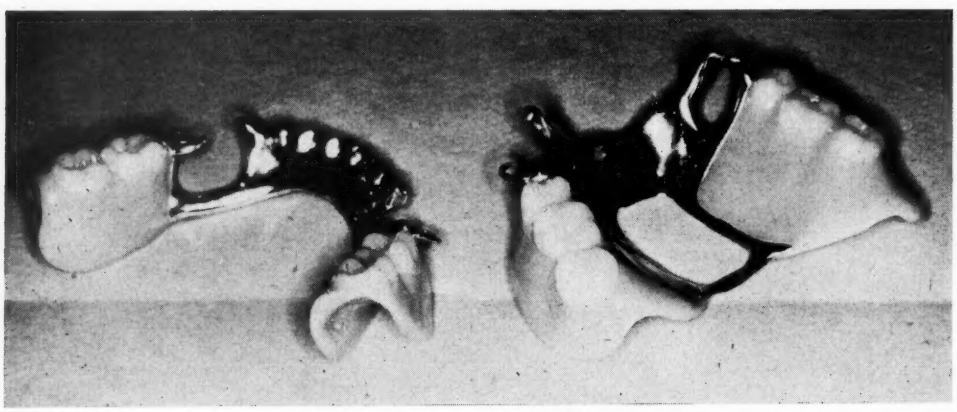


Fig. 3.—These class I partial dentures have resin bases, but frequently the base is made of cast metal. The lower denture has a linguoplate type of major connector. This maxillary partial denture has a posterior palatal bar. This unit may be omitted in some cases.

Mobility of teeth is reason for careful investigation of the area because the degree of recovery of the cervical bone is dependent upon the vitality of the osetogenic tissues. The restorative program must be planned so that the traumatized teeth are effectively stabilized to achieve bone regeneration. Frequently, this requires the splinting of adjacent teeth.

Caries Susceptibility.—Extreme caries susceptibility is a factor in making the choice between complete and partial denture service. Once the decision to retain the remaining teeth has been made, caries susceptibility is related to the type of tooth restoration to be supplied. Even though the patient may have shown complete cooperation in the exercise of caries control measures, with a satisfactory reduction of the bacterial count, complete crown coverage is indicated as a further protection against recurrent or new carious lesions. This creates a problem in esthetics when anterior teeth are to be restored, and, therefore, is a factor to be considered constantly in oral rehabilitation.

Size and Form of the Residual Ridge.—The subbasal support is a controlling factor in the choice of a partial denture, as it also may have been a potent reason

for not rendering complete denture service in the first place. If the ridge form is extremely poor (low, flat, and with reduced surface for support), adequate stress control will be a serious problem. Not only will this influence the choice of the type of restoration, but also the mouth preparation and the design of the appliance will need modification to meet possible magnified stresses. Stress control will become an acute problem when the mandibular ridge must support a restoration after lengthy disuse of the posterior edentulous areas.

Location of the Remaining Teeth.—The *location* of the remaining teeth is more important in partial denture construction than the number of teeth that are left. Root form and length, number of roots, crown form, form and bulk of the surrounding alveolar process, and the location of the remaining teeth in the dental arch are factors which are rated well above mere numbers.

CLINICAL CLASSIFICATION OF PARTIALLY EDENTULOUS SITUATIONS

A removable partial denture classification means little or nothing unless it also has clinical application. To say that the same type and design of partial denture is indicated in each situation where the same teeth are missing *is to presume that oral conditions never vary.* To presuppose that the potential abutment teeth and their supporting structures are equally capable where the same teeth have been lost is equally unrealistic.

Thus, it is improper to delegate (without proper instructions) the important step of designing the removable prosthesis to a laboratory technician. He must depend entirely on the cast, which shows only that certain teeth are missing. This practice is vulnerable because it completely disregards the adequacy of the oral structures to provide support. Planning and designing the removable partial denture must be done by the only person who can evaluate the oral condition—*the examining dentist.* The province of the laboratory technician *is to produce, but not to prescribe, the prosthesis.*

In choosing a basis for a classification, we should seek one which is fundamental. Nothing is more essential than *achieving support* for the needed prosthesis. The longevity and comfort of the denture is most dependent upon this factor.

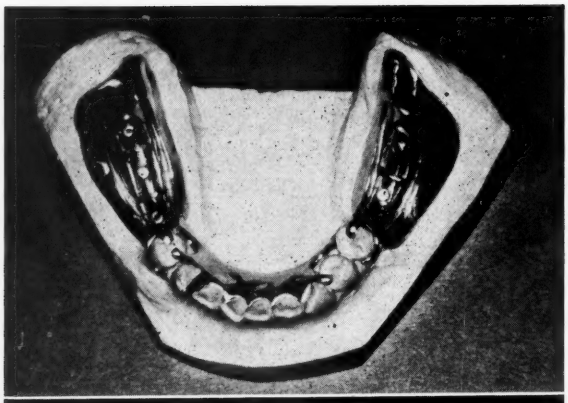
A classification system, to be applicable, must completely correlate with oral clinical conditions. The system also must be closely integrated with restoration design so that practical measures can be applied to keep induced stress loads within physiologic limits.

Six groups or classes are required to correlate the situations in semiedentulism and the conditions which are most commonly associated with each group. The proposed method is a classification of partially edentulous conditions based upon (1) the ability of the boundary teeth and their supporting structures to supply abutment facilities for the needed partial denture and (2) the location of the edentulous spaces in relation to the teeth which remain.[1]

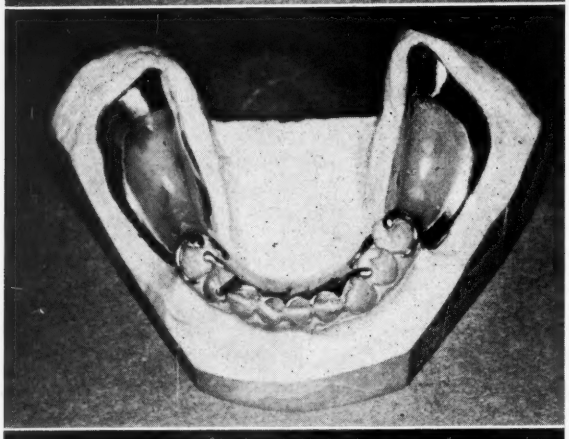
CLASS I

Class I represents an edentulous situation in which all remaining teeth are anterior to the bilateral edentulous ridges (Fig. 1*A*). This is the most frequently

A.



B.



C.

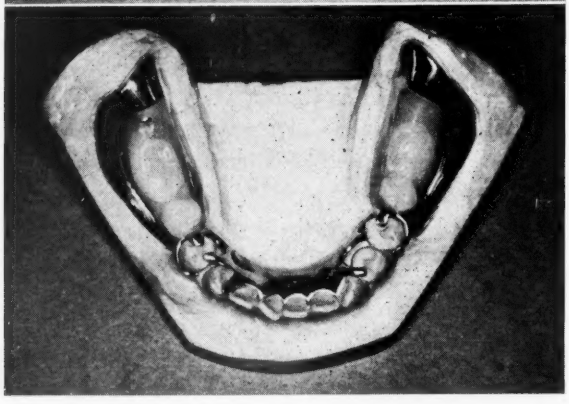


Fig. 4.—*A*, An exercise prosthesis is used to recondition the regions of alveolar disuse before placing a functional load on the depleted ridges. Note the maximum tissue coverage of the bases. *B*, each base has been covered with autopolymerizing resin. This restoration is worn for from 3 to 5 months without teeth. During this time the patient bites rapidly but lightly on a finger placed on the base near the abutment tooth of each side. This exercise is repeated frequently. Also, the patient alternately retains mouthfuls of hot and cold fluids to induce thermal stimulation. *C*, The restoration has been completed with the teeth placed in a balanced occlusal relationship. Note the narrowed occlusal surfaces.

occurring class, and its highest incidence is on the mandible. Often, the posterior teeth have been missing for many years.

The conditions commonly associated with class I are: (1) six to ten anterior teeth remain (Fig. 1*A*), (2) the boundary tooth may not be capable of unaided abutment function (Figs. 1, *B* and *C*, and 2, *B*), (3) resorption of the residual ridge is seen in varying extent (Fig. 1, *A* and *C*), (4) the immediate stability of the edentulous sector depends largely upon the period of disuse (Fig. 1, *A*—right side of class I arch—and *C*), (5) the ultimate stability of the residual alveolar bone is proportional to the ability which the patient has shown in maintaining the bone structure (Fig. 2), (6) malposition and irregularity of the remaining teeth may have resulted from their migration, and (7) reduced interarch space often exists posteriorly.

The removable prosthesis for class I permits no choice; it must be an extension-base partial denture of bilateral design (Fig. 3). Often, because of extensive disuse atrophy (Fig. 2), the use of the appliance without occlusal function as an "exercise prosthesis" is indicated (Fig. 4).[4] This is especially beneficial when an opposing complete denture must be used. The available subbasal support gives the maxillary denture a great advantage over the lower partial denture. Reconditioning the alveolar structure of the mandible first materially reduces this disadvantage.

The greatest variance in class I removable partial dentures is in mouth preparation. Splinting of adjacent teeth allows subnormal teeth to be retained when there is lowered physical tolerance, previous cervical bone loss (Figs. 1, *B* and *C*, and 2, *B*), or periodontal damage. In spite of such aid, the occlusal load often needs to be reduced when both tooth and ridge support are subnormal. Many class I dentures require reduced width of the teeth.[3] While this decreases the masticatory load, it will not lessen the stresses generated in bruxism. Only one point of occlusal contact is needed to transmit the occlusal force when the teeth are clenched. However, the occlusal forces are materially lessened by following the proper procedure in attaining harmonious occlusion first of the remaining teeth[5] and later of the artificial teeth.[4]

Class I conditions have occupied most of the attention of dentists in partial denture prosthesis. This situation will gradually change as more posterior teeth are reconditioned endodontically and periodontally to increase the frequency of tooth-borne (class III) restorations.

CLASS II

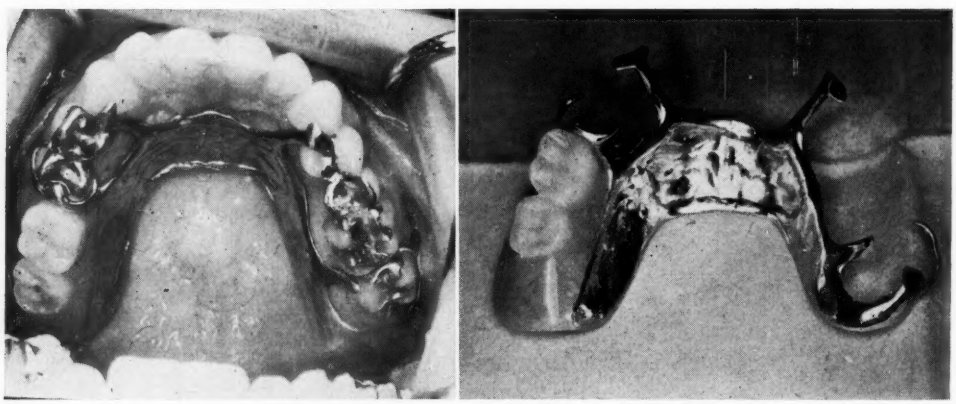
Class II situations are those in which remaining teeth of either the right or left side are anterior to the unilateral edentulous ridge (Fig. 5). The associated conditions of class I also may occur in a class II group. However, almost invariably, another characteristic is found in class II. Since all teeth remain on one side of the arch, the patient experiences less noticeable impairment of mastication. This makes him less inclined to seek replacement of the missing teeth until much disarrangement of the remaining teeth has taken place.

Because of this common occurrence, certain characteristics occur in addition to those noted for class I situations: (1) more disuse atrophy of the residual ridge is likely, (2) extrusion of the opposing teeth often is more extreme, (3) the alveolar process may have accompanied the occlusal movement of the teeth (Fig. 6), (4) extensive restoration of the opposing teeth is frequently necessary because of their occlusal disarrangement, (5) extraction of teeth which show extreme movement in the occlusal direction may be necessary, and (6) temporomandibular joint disability is more frequent in long-standing class II situations than in class I.

Replacement of unilaterally missing posterior teeth has often been neglected. Some patients who develop a temporomandibular joint syndrome report that no recommendation for replacement was made when their teeth were extracted.

A unilateral loss of posterior teeth induces occlusal imbalance and deflective occlusal contacts. Occlusal equilibration is temporary unless the missing teeth are replaced and occlusal balance is also achieved in the region of the missing teeth.

Class II patients generally are more able to maintain the alveolar processes. This may be the reason that the teeth of one side have been retained. There is less need to splint adjacent teeeth for multiple-abutment support than in class I situations. As with the class I restoration, there is little choice as to the type of removable partial denture. The extension base (Fig. 5) is mandatory because, unilaterally, no posterior abutment support remains.



A. *B.*

Fig. 5.—Teeth are missing posteriorly only on one side of the arch in the class II situation. The metal base is used in the maxillary arch more frequently than for lower partial dentures. Rebasing a maxillary base is not often necessary, because resorptive change is seldom encountered in a maxillary arch. For this reason, the use of an exercise prosthesis is not required for maxillary removable partial dentures. The problem of disuse atrophy is almost completely limited to the mandibular arch.

Occasionally, when posterior teeth have been lost, some portion of the occlusal function is replaced with a fixed prosthesis. This is done by splinting two or three adjacent teeth to support a fixed cantilever, distal extension. The method is used more often in class II but has been used bilaterally also. There is danger in this

practice. Destructive leverage is developed by such restorations. The restoration may *seem* to be satisfactory; however, should there be a physical decline for any reason, irreparable damage may be caused before any symptoms are noticeable clinically.

In addition, the residual ridge beneath the cantilever occlusal surface receives no stimulation and disuse atrophy occurs. Should this continue, the loss of ridge

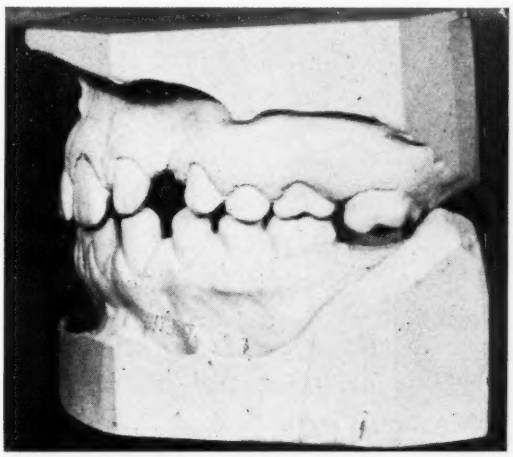


Fig. 6.—Extrusion of unopposed teeth is a condition which usually occurs more rapidly and to a greater degree in the maxillary dental arch. Often the alveolar process follows the tooth as it moves occlusalward. It is not uncommon to see an occlusal surface touching the pad of ridge-covering tissue. It may be necessary to extract perfectly good teeth which have migrated to such extreme positions.

height may be considerable and the disuse renders the bone unstable. Further resorption will occur beneath a complete-denture base if one is needed later. Occlusal imbalance follows. The use of fixed cantilever restorations for class I and class II situations is to be condemned.

CLASS III

Class III situations are those in which an edentulous space (Figs. *7A* and *7B*) is bounded by teeth both anteriorly and posteriorly. A distinguishing characteristic is that one or more boundary teeth are unable to assume the total abutment support of the prosthesis. These weak abutments require the aid of other remotely located teeth, allowing the principle of cross-arch splinting to be utilized to resist lateral tilting forces (Figs. *7C* and *7D*).

An occlusal stress load has two principal components of force, one directed vertically, the other inclined laterally. The boundary teeth are not capable of assuming the lateral stress in class III situations because (1) the edentulous span is long, (2) the abutment root form or length is unfavorable, (3) the cervical bone is depleted around the abutment teeth, and (4) the occlusal load is excessive.

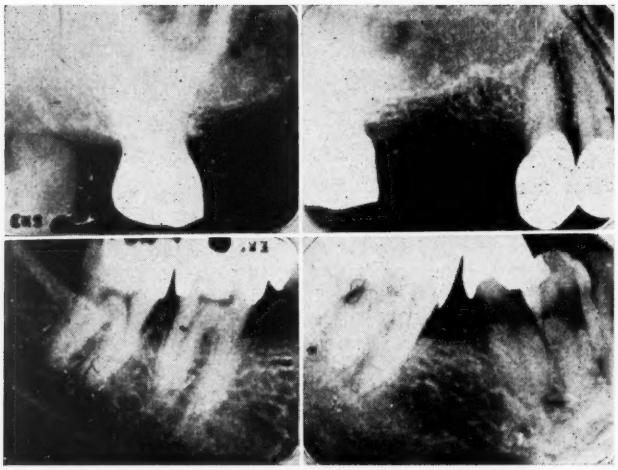


Fig. 7*A*.

A *unilateral* fixed or removable partial denture would probably fail because of inadequate protection against forces which produce lateral tilting. Zones of impingement of the periodontium would follow which might easily exceed the tolerance level of the patient.

A class III condition may involve the need for support from more than one tooth at each abutment site. When a combination of impairments is noted, the need for splinting of abutment teeth is apparent. However, the use of a *bilateral* design is necessary even when adjacent teeth are splinted together.

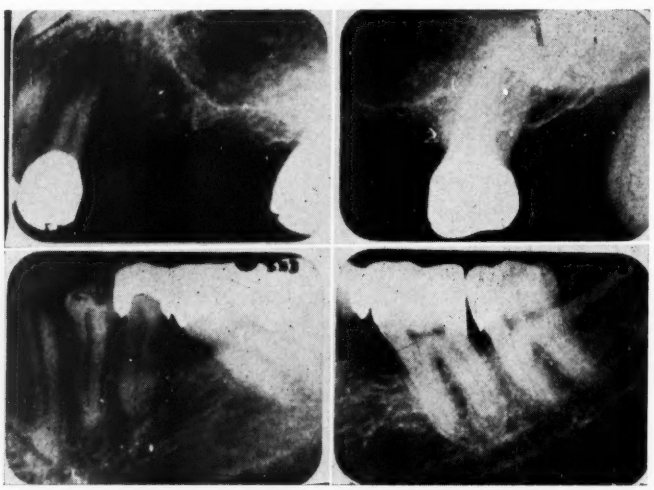


Fig. 7*B*.

Figs. 7*A* and 7*B*.—Roentgenograms show the typical class III situation. The teeth which bound the edentulous spaces are unable to assume the complete stress loads (both lateral and vertical) which abutment service would exert upon them.

Effective endodontic and periodontic therapy will save many molar abutment teeth, and therefore, more tooth-borne class III partial dentures will be needed, with a reduction of those in class I or II. These molar teeth, although weak or even mobile, can support the vertical load so long as the trajectory of the force is axial in its application.[2,6] The infrequent failures of fixed partial dentures that can be traced to overload are due to *lateral,* not vertical, stress loads. The removable tooth-borne prosthesis which is carried to the opposite side of the dental arch has

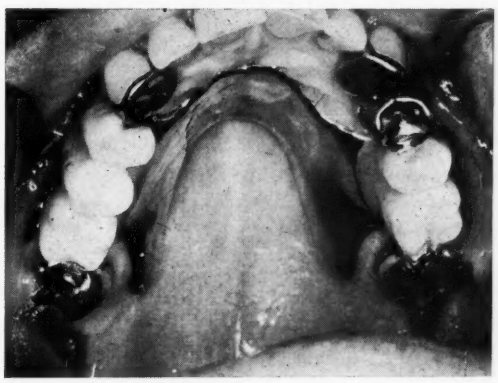


Fig. 7*C*.

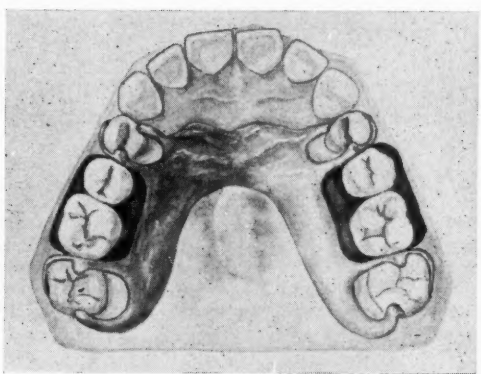


Fig. 7*D*.

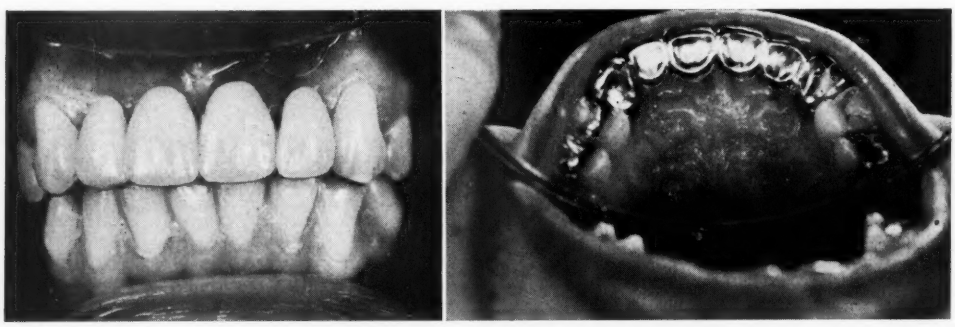
Figs. 7*C* and 7*D*.—Two bilateral designs are used to accomplish the necessary cross-arch splinting. With this effective control, these teeth not only can serve successfully as abutments but will show a marked decrease in mobility. The removable restoration in *C* is retained by precision attachments. The design in *D* has direct retainers of the clasp type.

a leverage advantage against lateral tilting forces which is very effective (Figs. *7C* and *7D*). The use of it makes a class III bilateral design so beneficial that mobile teeth may be expected to become firm and remain so when their environment is otherwise made favorable.

Two other advantages of the tooth-borne prosthesis over the extension-base, tissue-borne type are important. An occlusal load transmitted via a tooth reaches

the supporting bone through the principal fibers of the periodontal membrane as they are stretched from a relaxed to an extended state. By contrast, occlusal loads from an extension-base partial denture are transferred through its base to the mucosa and, by compaction of this pad of tissues, on through to the subjacent bone. This process is often accompanied by trauma from overload and possible prolonged interference with circulation (as in bruxism).

A class III prosthesis employs a safer, more physiologic method of transferring stress incident to occlusal pressures.[2] In addition to this protective measure, another important safety mechanism operates *involuntarily* to protect the tooth-borne restoration against overload. The periodontal membrane has rich proprioceptive (sensory) innervation which is thought to be absent from the mucosal structures. By this control, an involuntary reduction of occlusal forces is effected before there is actual realization of pain or discomfort. Hence, the periodontal membrane is protected, but the ridge covering is not. Perhaps this is one explanation of the excellent record of long service that tooth-borne fixed partial dentures have given.



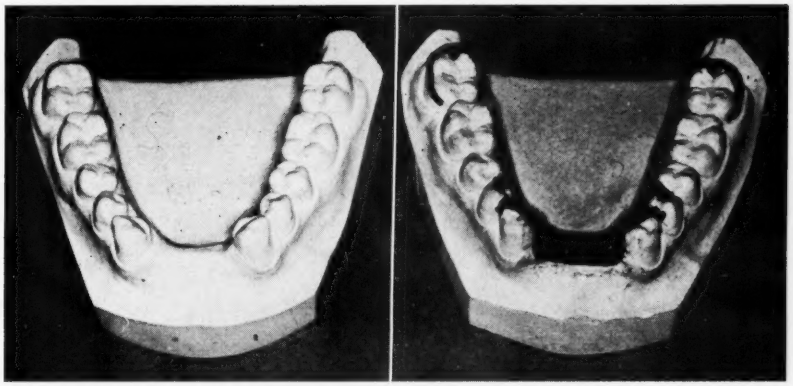
A. *B.*

Fig. 8.—The four incisors are supported by the ideal cuspid abutments. Note that the arc between the abutments is not severe. When the arch form is such that the arc becomes unfavorable, the abutment load may be made excessive because of the resulting leverage. In this situation, the adjacent bicuspids may be included in the abutment support by a splint union to form a multiple abutment. When the anterior class IV situation extends posteriorly beyond the cuspid, a removable prosthesis is usually indicated. (Courtesy of Prof. F. B. Vedder, University of Michigan, School of Dentistry.)

CLASS IV

Class IV situations are those in which the edentulous space lies anterior to the remaining teeth which bound it both to the right and left of the median line. This class is frequently exemplified by a loss of two or more of the incisors. The loss of one or both cuspids in addition to the incisors is less often encountered. Occasions when the anterior edentulous condition extends to include posterior teeth are infrequent.

When the space ends with teeth which can serve dependably as abutments (the cuspids are good examples), the prosthesis most often is of the fixed type (Fig. 8). This is somewhat less likely when the lateral incisors are the terminal teeth. Occasionally, when the arch form is such that it does not project anteriorly in an



A. *B.*

Fig. 9.—*A,* A class IV situation not only includes loss of the lower incisors but much of the alveolar process of the anterior ridge. The use of a fixed restoration (such as in Fig. 8) presents the difficulty of esthetically placing the pontic units. As a result of such bone loss, from accident or disease, a removable prosthesis usually is necessary so that a bulk of resin may be added to support the lip for a pleasing facial contour. If the patient also has a prognathic relationship, there is another advantage in using a removable prosthesis. With the cuspid abutments weakened by the labial loss of bone, they might become overloaded by the anteriorly directed prognathic stress load. By extending the design posteriorly *(B)* the support of all remaining teeth is enlisted to counteract these forces.

arc, a fixed prosthesis may even be preferred when the terminal teeth are first bicuspids. In such extreme use of the fixed partial denture, multiple-abutment support is necessary.

There are instances where the class IV situation calls for a removable prosthesis even when the restoration could be supported satisfactorily by the boundary teeth: (1) when excessive loss of alveolar bone (as in an accident or disease) requires a bulk of resin to support the facial structures (Fig. 9), (2) when support and retention must be gained from more and/or better abutment teeth, and (3) when wider distribution of the work load over a greater number of teeth is necessary.

The use of a fixed prosthesis when the missing anterior teeth extend beyond the cuspids involves two primary difficulties. First, there is the danger that sufficient rigidity of the fixed denture may not be attained. If there is the least flexibility, the porcelain tooth substitutes will be fractured. Second, the use of metal backings is necessary to obtain maximum strength, which may interfere with attainment of an esthetic result. A removable partial denture is superior in both respects, strength and appearance.

The most important advantage of a removable prosthesis in this situation, however, would be obtained by extending the framework to include the molars. A powerful counterleverage to resist the tendency of the replaced anterior teeth to be tilted anteriorly and upward during incision is developed by including the second molars as abutments (Fig. 10). The incisal edge appearance is superior because the porcelain or resin can be used with no metal backing.

The extension of the anterior edentulous space makes the problem of stress control progressively more complicated. Either a fixed or a removable restoration can be used, depending on which most effectively controls the induced stress loads.

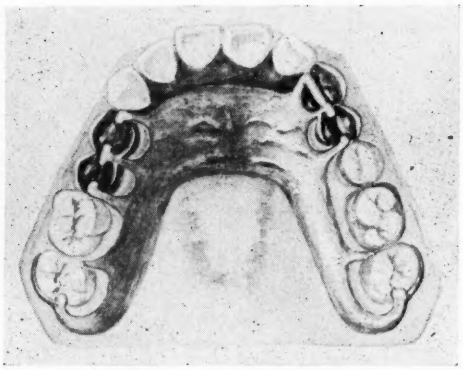


Fig. 10.—A removable prosthesis is used to replace the incisors and one cuspid. The remaining cuspid and adjacent bicuspid are united to form a multiple abutment, as are the two bicuspids of the opposite side. To accomplish this splinting, the restorations of choice are three-quarter (or complete) crowns. By survey of the wax patterns for these crowns, their forms may be so contoured as to provide lingual clasp retention. This eliminates any display of metal on the buccal surface by a clasp type of direct retainer. Another advantage is that the restoration may be extended posteriorly to enlist the aid of all remaining teeth in counteracting the forward and upward stresses which result from incising or clenching the teeth. Anchorage in the second molar regions not only provides adequate indirect retention but also develops a favorable counter leverage to resist anterosuperior force load on this long class IV denture. If there is loss of bone anteriorly, resin can be added on the labial surface so that the lip will be properly supported. Since no metal needs to be placed on the lingual surface of the anterior teeth, the removable appliance has the esthetic advantage of a better appearance of the incisal edges of the teeth.

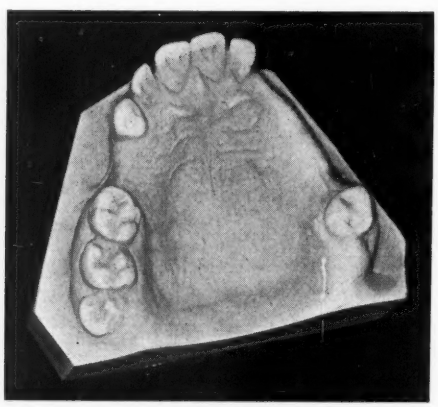


Fig. 11.—Class V is an infrequent situation. The lateral incisor usually presents a hopeless situation as far as provision of an abutment facility. A more satisfactory and esthetic result usually can be obtained by the use of an extension prosthesis which ends at the lateral incisor but does not utilize it for abutment service.

CLASS V

The class V edentulous situation is one with a space bounded by remaining teeth at its posterior and anterior terminals (Fig. 11). However, there is an essential difference between classes V and III. While the boundary teeth in

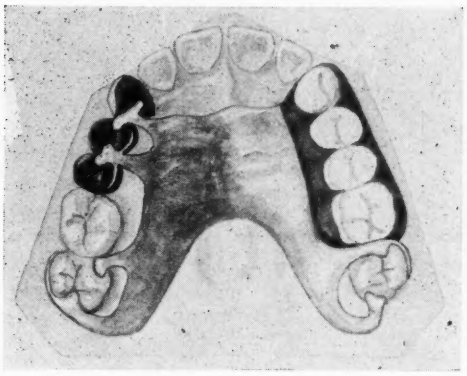


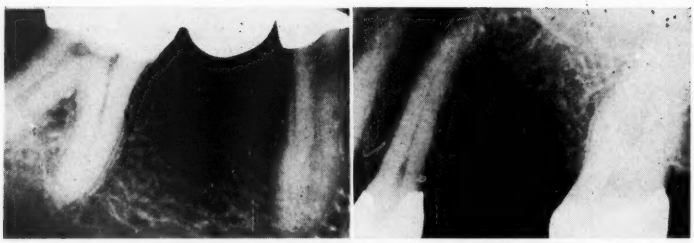
Fig. 12.—This design is suggested for a class V partial denture situation as seen in Fig. 12. This edentulous space terminates with a lateral incisor anteriorly but extends to the second molar posteriorly. The design solves the problem of procuring an abutment on the dentulous side when there is no edentulous space in that sector. By splinting the bicuspids and cuspids and changing the form of these teeth, lingual clasp retention is procured. Extending the framework to the right second molar gives effective indirect retention. If this strong abutment is also clasped, additional support can be gained to counteract the forces which tend to displace the class V denture in the anterolateral direction. In fact, by virtue of their contact, all of the remaining teeth aid in controlling this force. The anterolateral movement is restricted by a denture base of generous size which covers the anterior part of the hard palate, an area of excellent support.

class III can assume a portion of the abutment function (the vertical component of the work load), the anterior tooth which is a boundary in a class V condition cannot provide any abutment support. The distinguishing characteristics of this group are a long edentulous space and a very weak anterior terminal tooth.

A classic example of the class V condition is a space extending from a weak lateral incisor to the second molar (Fig. 11). For one or more of the following reasons, no satisfactory anterior abutment support is available: (1) the edentulous space is too long and the occlusal load would be excessive, (2) the form and length of the boundary tooth root is unfavorable, (3) there has been a loss of cervical bone around the anterior boundary teeth, and (4) splinting of adjacent anterior boundary teeth is not possible or it would not provide adequate abutment facility.

The prosthetic solution to the class V situation is a removable prosthesis of bilateral design with a free-end base which extends anteriorly (Fig. 12). Fortunately, class V problems are almost always in the maxillary dental arch, probably because of the vulnerable position of the upper cuspid to a blow on the face. With ample subbasal support to provide stability in a maxillary class V situation, an excellent result is usually obtainable. Since favorable indirect retention is available from the second molar of the opposite side, the class V partial denture also can be retained against the displacing force of gravity (Fig. 12).

Whenever there is a possibility of splinting the weak lateral incisor to the central incisor, this should be done. The removable prosthesis is then a bilateral class III type. When this cannot be done, however, the class V design must be utilized.



A. *B.*

Fig. 13, *A* and *B*.—The class VI edentulous situation is one in which the boundary teeth are able to assume the total abutment function. Such favorable conditions are seen in the roentgenograms. *A*, Usually the restoration should be a fixed prosthesis. Properly designed, the clasp-retained removable restoration may be used in the limited instances in which it is indicated. *B*, The roentgenogram of a class VI situation taken nearly 15 years after the placement of the removable prosthesis seen in Fig. 13*C*.

CLASS VI

Still another edentulous situation has boundaries of teeth remaining anteriorly and posteriorly. Thus, three of the six groups have the same anatomic landmarks. However, class VI conditions are always such that the complete occlusal load can be tooth borne and, therefore, a fixed or removable *unilateral* prosthesis is possible (Fig. 13, *A* and *C*).

Because the abutments must bear both vertical and lateral components of the occlusal load, there are definite limitations under which the unilateral tooth-borne prosthesis can succeed. These conditions include: (1) the edentulous space should be short (Fig. 13), and/or the occlusal work load limited, (2) the abutment root length and form must be favorable (Fig. 13, *A* and *B*), and (3) there should be minimal cervical bone loss with ample evidence of the ability to pro-

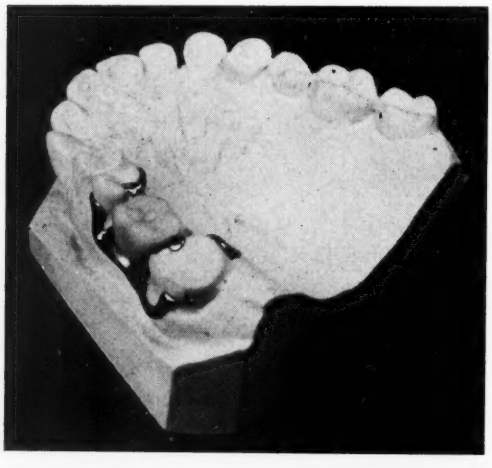


Fig. 13*C*.—The removable prosthesis. This patient was past 50 years of age when the denture was first placed.

vide adequate bone maintenance. The abutment tooth should exhibit minimal mobility, and the crown form of the boundary teeth must present adequate retention for either the fixed or removable prosthesis.

In such instances, the fixed prosthesis is the restoration of choice.[4] No prosthodontic procedure has a better clinical record than does the unilateral fixed partial denture if used within the indicated limits. However, no prosthesis has had a less favorable record than the unilateral removable partial denture (Fig. 13*C*). The reason is not that the work loads are transferred in a less desirable physiologic manner, but rather, the clasp retainers are not properly located so that the rotation of the denture can be prevented. While this defect can be avoided easily, it is advisable to curtail the use of the removable denture in class VI situations. When properly designed and executed (Fig. 13*C*), a removable unilateral partial denture can be used with complete confidence that it will be comfortable, efficient, and of long duration of service.

SUMMARY

Because the Kennedy classification of removable partial dentures has many excellent features and is established,[7] it is urged that this classification be retained and simply modified. The addition of two groups provides six classes with which to designate different structural and anatomic situations that require dissimilar designs.

Within the proposed classification, there exists a logical correlation with the principles of design and construction of removable partial dentures. Unless the same principles are applicable in the design of such restorations when the same oral conditions are present, something less than principles is being applied. There can be but one logical conclusion. There has been an inaccurate grouping, and this grouping needs to be changed.

The suggested classification eliminates the defects in a practical manner. However, the advantages of an established method of classification of partially edentulous conditions are not lost.

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TREATMENT OF ADVANCED PERIODONTAL DISEASE BY PROSTHODONTIC PROCEDURES

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UNTIL THE BASIC CAUSES OF PERIODONTAL DISEASE are determined and specific cures are established, dentists will continue to be confronted with the problem of how best to treat patients who present a rapidly advancing type of periodontal disease.

Close cooperation between the periodontist and the prosthodontist is indicated when it becomes evident that periodontal treatment and necessary systemic therapy are not arresting the rapid loss of bone about the roots of the teeth. Pre-extraction profile records should always be made at this time.[1]

Treatment procedures which include certain prosthodontic services often produce spectacular results, especially when they are instigated before the loss of tooth-supporting bone has reached the hopeless stage. The following case history illustrates the beneficial results which may be gained by collaboration between the periodontist and the prosthodontist.

CASE HISTORY

A 38-year-old woman was referred to me in 1932 by her periodontist, who had decided that further treatment of the patient's periodontal disease was not indicated and that all of her teeth should be extracted. After making a thorough study of the case, I felt that favorable results might be obtained through a more conservative approach. So I prevailed upon the periodontist and the patient to limit the extractions to the maxillary teeth and to continue treatment of the mandibular teeth.

The mandibular teeth were in fair alignment, but their occlusal surfaces required some alteration by selective grinding to develop the best possible state of balanced occlusion. Immediately after these occlusal adjustments, a complete maxillary denture was constructed.

Within a few weeks after insertion of the maxillary denture, the periodontal condition of the mandibular teeth began to improve, and within 6 months it was evident that the patient could probably retain her mandibular teeth for some time. This observation proved to be correct, and the patient was provided with routine periodontal and denture care.

The periodontist died, and in 1935 I moved from the patient's locality.

Nineteen years later I learned, from the dentist to whom the patient had been referred, that she had not lost any of the mandibular teeth and that there was no sign of active periodontitis about these teeth. She was in good health and required only occasional denture service.

No type of bracing framework was used on the mandibular teeth for this patient. The use of bracing frameworks may be beneficial, however, and I now generally use them in these cases. Frequently, they may be included in the design of a removable partial denture. Although the results for this patient were very gratifying, not all cases respond so favorably to this type of treatment, especially for such a long period of time.

Read before the Academy of Denture Prosthetics in Louisville, Ky.

RATIONALE OF TREATMENT

The rationale that prompted my advice in this instance is applicable in many similar situations. It might be summarized as follows:

1. Periodontally diseased teeth usually respond better to periodontal treatment when the occlusal forces applied on them are reduced.

2. Occlusal forces on the natural teeth in one jaw are decreased when the opposite jaw is supplied with a complete denture, because patients cannot apply as much closing force with a complete denture as they can with opposing natural teeth.

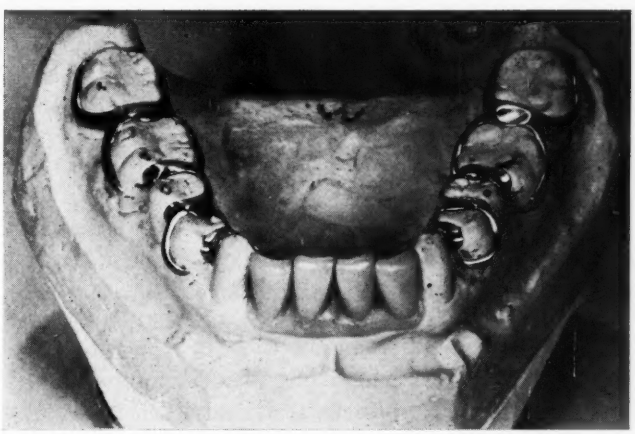

Fig. 1.—A partial denture which supplies the four lower incisors. The metal framework is shaped to engage all remaining natural teeth and brace them against individual horizontal movement. As a result of proper mouth preparation before making the final impression, the occlusal surfaces of the metal framework are in harmony with the natural occlusal plane alignment.

3. Many patients who are experiencing periodontal disease have little or no interocclusal clearance, but this fault can be corrected when one jaw is supplied with a complete denture.

4. It is often possible to provide the patient with an improved, balanced occlusion when one jaw is supplied with a complete denture.

5. Maxillary complete dentures are usually more satisfactory than mandibular complete dentures.

6. The presence of a complete denture in one jaw (the maxillary, but never the mandibular denture in these cases) encourages more vigorous home care of the remaining natural teeth.

The health of the patient must be the first consideration, and consultation with his or her physician is advisable before formulating any extensive treatment plan. Patients with systemic conditions which indicate a low tolerance to infection may require extraction of all of the natural teeth. Such a decision should not be made hastily, however, because the response of mandibular teeth to periodontal treatment is often spectacular when they are opposed by a complete denture.

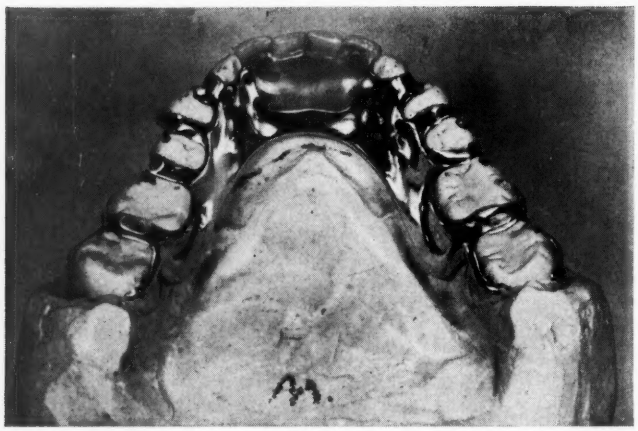

Fig. 2.—If and when other natural teeth are lost, they can usually be added to a partial denture of this type. The closed double bar (lingual bar and continuous clasp) design was used to prevent the packing of food against the receded gum crest and the upper edge of a regular lingual bar.

TREATMENT PLAN

The following course of treatment is recommended when it has been decided that periodontal treatment of opposing natural teeth and the necessary systemic care are not arresting the loss of supporting bone about the roots of the teeth and that a more extensive type of treatment seems advisable.

Extract the remaining posterior teeth in the maxillae and any "hopeless" posterior teeth in the mandible. If the treatment plan calls for the extraction of mandibular anterior teeth, their removal can be delayed until an immediate type of removable partial denture has been constructed.

Continue periodontal treatment of all mandibular teeth that are to be retained while the recent extraction areas are healing.

If any mandibular teeth are missing or are to be extracted, construct a mandibular partial denture. The metal framework of the partial denture should be designed to engage and brace the retained natural teeth and thus cause them to function as a single unit when horizontal forces are applied (Figs. 1 and 2). In some instances, it may be advisable to construct a removable metal framework to brace the natural teeth even though none are missing. Usually, third molars would be extracted.

Construct an immediate maxillary complete denture, making sure that the occluding vertical dimension will provide for an acceptable interocclusal rest clearance. The use of resin anterior and posterior teeth is advisable. Resin teeth tend to reduce occlusal impacts on the opposing natural teeth. They also cause less wear on opposing metal tooth restorations and metal frameworks. Resin teeth wear away more rapidly than do porcelain teeth and thus help to maintain a better state of occlusal balance.

ESTHETIC APPEARANCE AND BALANCED OCCLUSION

Because of the extreme vertical overjut of the natural anterior teeth of many patients, it is often impossible to reproduce their natural appearance (if such is desired) and also establish a satisfactory occlusal balance in lateral jaw positions. It is fortunate, however, that the appearance of many patients is improved when they are provided with anterior tooth arrangements which have less vertical overjut than was present with the natural teeth.

If the mandibular incisor teeth have erupted beyond the proper occlusal level until they impinge or nearly impinge on the anterior palatal mucosa, they should either be shortened by grinding or be extracted and replaced with artificial substitutes, positioned at a lower level, on a partial denture.

If the natural maxillary anterior teeth are overly long and the mucosa is exposed during speech or when smiling, the artificial anterior teeth should be positioned at a higher level for a more esthetic effect.

Shortening of the maxillary and/or mandibular anterior teeth will flatten the incisal guidance and will simplify the establishment of a desirable occlusal balance in lateral relations.

The desired appearance should not be sacrificed for protrusive occlusal balance. Clinical experience with many complete dentures has proved the accuracy of this contention. The best possible lateral occlusions, within a short range of mandibular movement, should always be established.

CONCLUSIONS

The treatment procedure recommended here cannot be considered as a sure method of preserving the remaining mandibular teeth in all cases of periodontal disease. However, the results obtained with a large number of patients warrant its trial. Patients do appreciate the delay, if only partial and temporary, in the transition from the dentulous to the edentulous state.

It would not be possible to delineate all types of cases that might be treated as suggested here. Such decisions must be based on the situations presented by the individual patient.

Close cooperation between the periodontist, the prosthodontist, and frequently the patient's physician is advantageous to all concerned, especially to the patient.

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OCCLUSION IN REMOVABLE PARTIAL DENTURES

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THE ROLE OF OCCLUSION in the successful treatment of removable partial denture patients is a major one. Many thoughtfully designed and skillfully fabricated removable partial dentures fail because an adequate occlusal pattern was not developed during the treatment period.

The objective in treating a partially edentulous patient is not merely to replace the missing teeth but to construct a partial denture that functions in harmony with the other structures of the mouth. Much of the success of removable partial dentures depends on the ability and skill with which the total occlusal pattern is developed. The occlusal surfaces of the remaining natural teeth and of the artificial teeth must be skillfully harmonized so that the stresses to which they are subjected will be well distributed and tolerated. The combined occlusal pattern of the partial denture and remaining natural teeth must be adjusted to function harmoniously with the other parts of the masticatory system. All of the individual structures comprising the mouth must be brought into a state of harmony and maintained there.

A clear understanding of the term "occlusal harmony" is basic to the attainment of a desirable, coordinated occlusal pattern. The informed dentist separates the occlusal factor into its various component parts, analyzes each in relation to the other, and then plans the necessary treatment to establish a coordination of these components. The goal is an occlusal pattern in which there are (1) simultaneous contact between the upper and lower teeth and (2) absence of cuspal interference in the various mandibular excursions.

In whatever position the teeth in one jaw are brought into contact with their antagonists, they should touch simultaneously with no deflecting occlusal contact. Throughout the entire range of occlusal movement, the contacting teeth should glide freely and without cuspal interference. Many removable partial dentures fall short of this goal of complete occlusal harmony.

STAGES OF INCORPORATION OF OCCLUSION IN PARTIAL DENTURES

The adequate occlusal pattern of a completely successful removable partial denture is the result of accommodating the occlusion at each of the following stages:

Read before the Pacific Coast Society of Prosthodontists in Portland, Ore.

The opinions and assertions contained in this article are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

Analysis of Occlusion of Remaining Natural Teeth.—The first step is to analyze the occlusion of the remaining natural teeth and recognize any disharmony between the teeth and the temporomandibular joint.

Equilibration of Natural Teeth.—All discrepancies in the occlusal surfaces of the natural teeth must be corrected to bring the occlusal pattern of these teeth into harmony with the jaw relations and movements produced by the temporomandibular joints and the neuromuscular system.

Occlusion of Artificial Teeth.—After the natural teeth have been balanced and harmonized with the temporomandibular joints, this same harmonious pattern must be built into the occlusal surfaces of the artificial teeth.

Coordination of Occlusal Pattern.—When the restoration is inserted in the mouth, final coordination of the occlusal surfaces of the artificial teeth with the natural teeth and temporomandibular joints must be developed.

A removable partial denture will give the patient the maximum in comfort, efficiency, and longevity only when the occlusion is accommodated at each of these four stages. To achieve this ideal occlusal pattern, the mechanical relationship between the temporomandibular joints and the occlusal surfaces of the teeth must be understood and a practical technique for applying this knowledge to removable partial denture construction must be developed.

FACTORS THAT INFLUENCE OCCLUSION

Occlusion is the contacting relation between the occlusal surfaces of the maxillary and mandibular teeth. Occlusion is influenced by (1) the temporomandibular joints, (2) the mandibular musculature, and (3) the occlusal surfaces of the teeth. Each of these factors guides the jaw to certain definite positions. A knowledge of these factors and of the jaw positions they prescribe is necessary to understand our approach to the occlusal problem.

JAW POSITIONS

Those Determined by the Temporomandibular Joint.—The basic jaw positions are those relationships between the upper and lower jaws as determined by the structure of the temporomandibular joints and the neuromuscular system. They are centric relation, left lateral relation, and right lateral relation. The two-dimensional needle-point tracing which an edentulous patient scribes by moving the jaw in a horizonal plane is useful in visualizing these positions. The position of centric relation is indicated by the apex of the tracing. It is the posterior terminal relation or border position of the mandible. From centric relation, the jaw can move to a multitude of right and left lateral and protruded positions. The outermost right and left border movements scribe the sides of the tracing, and any border position on the right or left side of the tracing is referred to as a right or left lateral relation. The apex of the tracing and all points down each side indicate jaw positions determined by the temporomandibular joint and its musculature. When an opening component or third dimension, such as a cuspal rise, is incorporated into the lateral movement, similar border positions are reached as directed by the temporomandibular joint.

Those Determined by the Teeth.—The cusps or inclined planes of the occlusal surfaces of the teeth also produce a series of jaw positions. They are termed "centric occlusion, left lateral occlusion, and right lateral occlusion." Centric occlusion is that tooth relationship in which the upper teeth are in tight maximum intercusping with the lower teeth. When a right or left lateral excursion is made with the teeth in contact, the inclines of the cusps guide the jaw to the lateral positions of maximum intercusping. These positions are termed "left lateral occlusion and right lateral occlusion." The position of maximum intercusping of the opposing teeth and all left and right lateral positions of maximum intercusping are jaw positions determined by the occlusal surfaces of the teeth.

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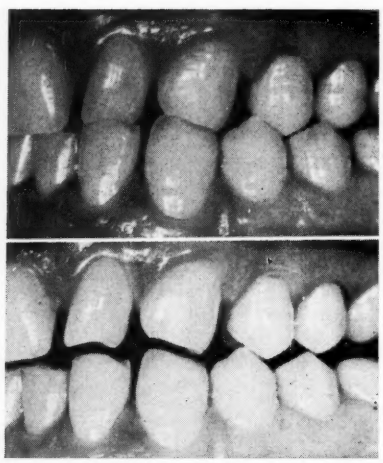

B.

Fig. 1.—*A*, The occlusion and jaw relation prescribed by the tight intercusping of teeth cause the mandible to be in a slightly protruded position. *B*, The jaw relation prescribed by the temporomandibular joints causes the bicuspids to contact on inclined planes. A closing force will cause the mandible to slide forward to an intercusping tooth position.

OCCLUSAL HARMONY

In terms of jaw positions, occlusal harmony means that the positions determined by the teeth are identical to the jaw positions determined by the temporomandibular joints. In other words, centric occlusion of the teeth occurs when the jaws are in centric relation, and left and right lateral occlusions of the teeth occur when the jaws are in left and right lateral relations, respectively. Occlusal harmony means that the occlusal surfaces of the lower teeth function in harmony with the occlusal surfaces of the upper teeth and that this occlusal pattern is perfectly coordinated with the anatomic structure of the temporomandibular joints.

OCCLUSAL PROBLEM

The occlusal problem is to recognize the jaw positions as determined by the temporomandibular joints, the jaw positions as determined by the teeth, and any difference between these two sets of positions and then to correct the differences.

Obviously, the temporomandibular joints cannot be corrected to fit the teeth, so the teeth must be reshaped to fit the requirements of the joints. The occlusal surfaces of the teeth must be ground to meet in simultaneous contact in the basic jaw positions as determined by the joints and to perform multidirectional, free-gliding lateral and protrusive movements between these positions.

DETECTION OF OCCLUSAL DISHARMONIES

Detection of occlusal disharmonies is often difficult because of the inability of the patient to move his jaw consistently in the desired direction and to the desired position. When the initial contact between the upper and lower teeth is at the inclined surfaces of the cusps, these surfaces cause the jaws to shift to a more stable occlusal relation, which may result in an incorrect occlusal diagnosis (Fig. 1).

The patient's mouth must be used as a positional articulator in order to effectively analyze and equilibrate the occlusion. Attempts to analyze centric relation and centric occlusion on casts mounted on an articulator frequently fail because of the difficulty of recording and verifying the centric relation mounting of the casts. It is impossible to analyze lateral relation and lateral occlusion on the articulators commonly used, because they seldom reproduce accurately either the lateral positional relations or the jaw movements. Because of the limitations of most articulators, mounted casts are of little use in preparing a detailed list of cusps to be reshaped during the equilibration technique. Occlusal disharmonies in natural teeth are in the mouth and may not exist on the articulated casts. These disharmonies must be located in the mouth and must be corrected in the mouth; the mouth itself must be used as an articulator when doing this work.

OCCLUSAL COORDINATOR

Jeffreys[1] has described the "occlusal coordinator," a simple device which is constructed individually for each patient. It is most useful in the study and correction of occlusal disharmonies. The coordinator makes it possible to control the jaw in its various positional relations and simplifies recognition of discrepancies in the jaw positions determined by the teeth and by the temporomandibular joints.

The coordinator consists of a maxillary and a mandibular part each made of cold-curing acrylic resin on casts of the patient's mouth. The mandibular part holds an anterior bearing screw immediately behind the anterior teeth (Fig. 2). The maxillary part is a flat plane against which the rounded end of the lower bearing screw can slide or rest (Fig. 3).

The mandibular part of the occlusal coordinator is made by (1) forming a wax dam from the interproximal space between the left bicuspids across the floor of the cast to the interproximal space between the right bicuspids, (2) waxing a nut and bolt upright, immediately lingually to the anterior teeth, with the nut at the height of the middle third of the teeth, (3) filling the dam with a creamy consistency of cold-curing acrylic resin to a level which completely embeds the nut, covers the lingual cusps of the first bicuspids, and approaches the incisal edges of the anterior teeth, and (4) when the resin has cured, freeing the bolt and trimming

the resin to fit the mouth. A thin layer of resin is maintained over the lingual cusps of the first bicuspids to provide vertical support. The bolt is shortened, and its end is rounded and polished.

The maxillary part of the coordinator is constructed in a similar manner, but without the nut and bolt. The resin is built up to a height sufficient to cover the gingival third of the teeth. It is trimmed horizontally, parallel to the occlusal plane, and smoothed against a flat abrasive surface.

ANALYSIS OF OCCLUSION OF REMAINING NATURAL TEETH

An analysis of the existing occlusal pattern of the natural teeth is necessary to determine whether or not harmony exists between the teeth and the temporomandibular joints. If a disharmony is found, the occlusal pattern must be corrected before any large fillings and crowns are placed, before the occlusal rests are prepared, and before the final impressions are made.

The occlusal coordinator is extremely valuable when studying occlusion and locating disharmonies between the teeth and the temporomandibular joints. With the screw raised sufficiently to keep the teeth out of contact, the patient can move the jaw freely with only the temporomandibular joints and the musculature guiding it. In effect, the equivalent of the edentulous condition is established. When a lateral

Fig. 2.

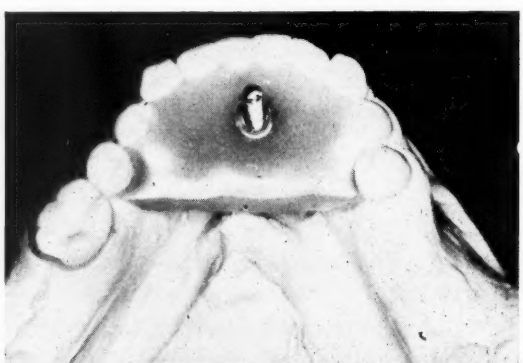

Fig. 3.

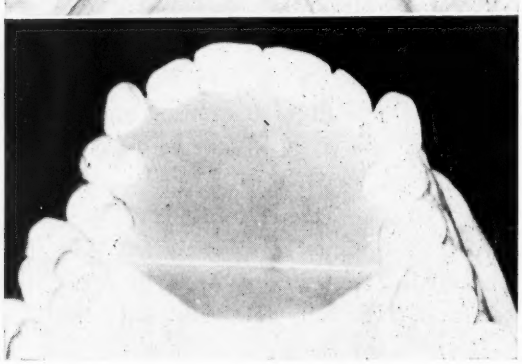

Fig. 2.—The mandibular part of the occlusal coordinator is in position on the lower cast.
Fig. 3.—The maxillary part of the occlusal coordinator is in position on the upper cast.

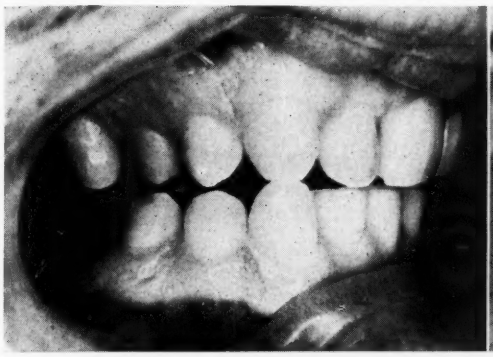

Fig. 4.

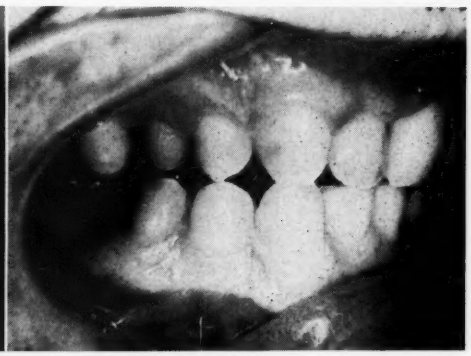

Fig. 5.

Fig. 4.—The coordinator is in the mouth with the bearing screw adjusted to the point of initial contact between the inclined planes of the upper and lower teeth. The jaws are in the position prescribed by the temporomandibular joints. The screw coordinator prevents any further closure and eliminates the tendency of the inclined planes to shift the jaw from this position to the one prescribed by the teeth.

Fig. 5.—Without the coordinator in the mouth, the inclined planes shift the jaw to the tooth position, making positional occlusal discrepancies difficult to recognize.

excursion is made, the jaw is guided by the temporomandibular joints and the needle point moves along the side of the tracing which could be made at that particular opening. By varying the height of the screw, the coordinator enables the mouth to be used as a positional articulator. The jaw positions prescribed by the temporomandibular joints can be studied in the mouth and compared with the jaw positions prescribed by the teeth. The coordinator is especially useful in studying occlusion in partially edentulous patients in whom mutilated occlusions are complicated by elongated and drifted teeth.

The completed coordinator is adjusted to fit the patient's mouth so that it does not interfere with the teeth as they close in centric position. The amount of closure allowed to the mandible and the teeth can be varied by raising or lowering the threaded screw. The screw is adjusted to that height which will permit the initial

Fig. 6.—The natural teeth are equilibrated to the position prescribed by the temporomandibular joints by use of the occlusal coordinator.

contact between the inclined planes of the upper and lower teeth in extreme lateral excursions. The screw absorbs the load, prevents any further closure, and makes it possible for the patient to maintain this jaw position of initial contact on the inclined planes without sliding. This position could be seen on a needle-point tracing; it is a lateral jaw position prescribed by the temporomandibular joint and its musculature (Fig. 4). Without the coordinator, the inclined planes of the contacting teeth

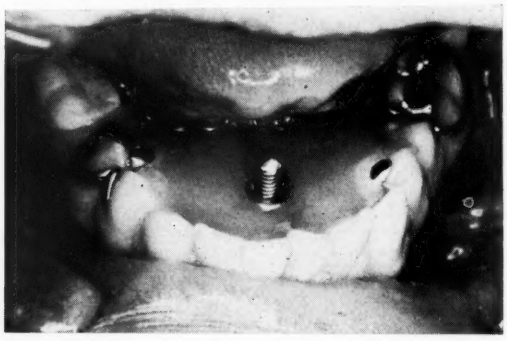

Fig. 7.—The removable partial denture is inserted and the coordinator is in position for the final occlusal correction of the artificial teeth.

quickly shift the jaw to the *tooth* position, and positional occlusal discrepancies are difficult to recognize (Fig. 5). All occlusal discrepancies detected by this analysis should be removed by equilibration.

USE OF OCCLUSAL COORDINATOR IN EQUILIBRATION OF NATURAL TEETH

The occlusal coordinator simplifies the correction or reshaping of natural teeth to bring their occlusal pattern into harmony with the jaw relations and movements produced by the temporomandibular joints and the mandibular musculature. The use of the coordinator makes the temporomandibular joints (not the teeth) the guiding factor in determining the positional relations during the equilibration technique. The initial contact between the inclined planes of the upper and lower teeth can be maintained without jaw movement to the tooth-prescribed position. A carbon or wax "grinding" mark thus obtained is an accurate one and is not distorted by a sliding movement toward the tooth-prescribed position. If the teeth are used as the guiding factor in establishing the positional relations, the teeth may be ground to fit together tightly but disharmonies between the teeth and the joints will not necessarily be eliminated.

The coordinator screw is adjusted to permit initial contact between the teeth in the extreme lateral position, and a working-side grinding mark is obtained. All working-side interferences are eliminated by grinding to reduce the interfering buccal cusps of the upper and the lingual cusps of the lower teeth. The "BU-LL" rule is followed. Good cuspid contact is preserved in the extreme lateral relations. Balancing-side interferences are also marked and ground at this same jaw opening and position.

After these first points of interference are eliminated, the coordinator screw is lowered one turn to permit further jaw closure. New points of interference are marked and corrected on both the working and balancing sides. The correction process is continued until all points of interference on both the working and balancing sides have been corrected in the extreme lateral positions (Fig. 6) and in the various positions down the inclined planes of the cusps until the centric position is reached. By careful adjustment of the pin, carbon marks of deflective centric occlusal contacts can be registered, and at the same time, the pin prevents sliding and marking of teeth other than those actually making the deflective contacts. The interfering contacts in centric occlusion are eliminated until the teeth make simultaneous contact in the centric jaw position prescribed by the temporomandibular joints.

Then, the occlusion in the protruded relation is corrected, and the angulation of the inclined planes is adjusted to centric relation. After this correction has been completed, the teeth are smoothed and polished.

CUSP HEIGHT OF ARTIFICIAL TEETH

After the occlusal pattern of the remaining natural teeth has been corrected, the final impressions are made, the framework is constructed, and the casts are mounted on an articulator. Then the artificial teeth are selected. Since the artificial teeth will be set to correspond with the occlusal pattern of the natural teeth, the selection should be based on the cusp height of the natural teeth: if the natural teeth have steep cusps, the artificial teeth should have steep cusps; if the natural teeth are worn and have shallow cusps, corresponding artificial teeth with low cusps

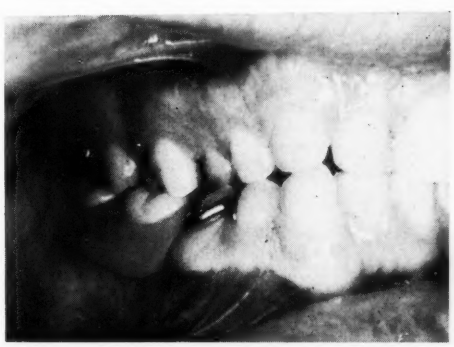

Fig. 8.—The occlusal pattern of artificial teeth is in harmony with the pattern of the natural teeth and the temporomandibular joints.

should be selected. The buccolingual width of the artificial teeth should be considerably narrower than that of the corresponding natural teeth. This will reduce the amount of stress transmitted from the occlusal surfaces of the artificial teeth to the residual ridge. Most artificial teeth are comparatively narrow, but often it is desirable to grind them to an even narrower width to reduce the occlusal stresses.

ARRANGING THE ARTIFICIAL TEETH

The artificial teeth are arranged on the articulator to occlude correctly in centric relation and to intercuspate in the lateral relations in as much harmony with the occlusal pattern of the natural teeth as the articulator permits. Articulators vary in their capability for movement and adjustment. The more accurately the articulator can reproduce jaw movements and jaw positions, the less occlusal adjustment is required when the restoration is placed in the patient's mouth. If the articulator does not reproduce the jaw movements accurately, the occlusal pattern of the partial denture will require considerable correction in the mouth.

CORRECTION OF THE OCCLUSION OF THE PARTIAL DENTURE IN THE MOUTH

The occlusal coordinator is trimmed so it will fit the cast with the waxed-up partial denture in position. The removable partial denture is then processed and polished. At the time the denture is seated in the patient's mouth, the coordinator is positioned (Fig. 7) and the occlusal pattern of the removable partial denture is made to harmonize with the pattern of the natural teeth and the temporomandibular joints (Fig. 8).

SUMMARY

For a successful removable partial denture, the occlusal pattern of the natural teeth should be harmonized with the temporomandibular joints, and this same occlusal pattern should be incorporated into the artificial teeth. When this procedure is followed, the comfort, efficiency, and longevity of the removable partial denture is greatly enhanced.

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FIXED PARTIAL DENTURES

THE IMPORTANCE OF CENTRIC OCCLUSION IN DIAGNOSIS AND TREATMENT PLANNING

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THE INITIAL POINT OF CONTACT OF TEETH during a mandibular closure into the terminal hinge position is fundamental to diagnosis and treatment planning for dentulous patients. This tooth relationship is termed centric occlusion.

The definition of the terminal hinge position locates the condyles in their most retruded position in the glenoid fossae.[1] This concept allows attention to be focused on a tooth relationship while the condyles have a specific correlation in the fossae. Therefore, in centric occlusion there may be an ideal cusp arrangement in this mandible-to-maxillae relationship; or possibly only one cusp of one mandibular tooth may occlude with a cusp of a maxillary tooth (Fig. 1).

This first tooth contact, regardless of the cusp relationship, is centric occlusion. After this initial contact, the mandible often shifts to bring more teeth into occlusion. This is eccentric occlusion. In closing into eccentric occlusion, the mandible follows the dictates of the neuromuscular system. The proprioceptive impulses received from receptors in the periodontal membrane cause a reaction which attempts to produce a closure that avoids the traumatic effect of deflective occlusal contacts.

OBJECTIVE OF TERMINAL HINGE POSITION

When examining patients, there is an objective to manipulating the mandible into its most retruded or terminal hinge position. If the teeth are tapped together rapidly, overcoming the neuromuscular pattern of closure which the patient has developed, the mandible can be placed readily in the terminal hinge position and the first point of contact between teeth can be observed. Only in this way can the philosophy of McCollum be followed: "It is easy to understand that our diagnosis in our plan of treatment will be no better than our concept of health and our service to our patient will be no better than our ability to differentiate the smallest deviation from the normal."[2]

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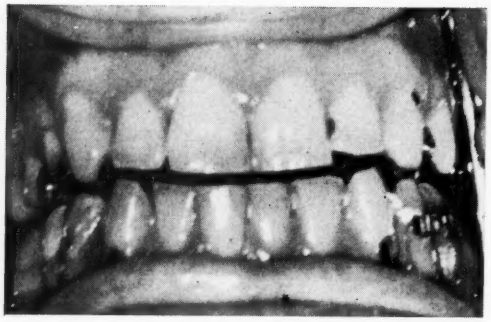
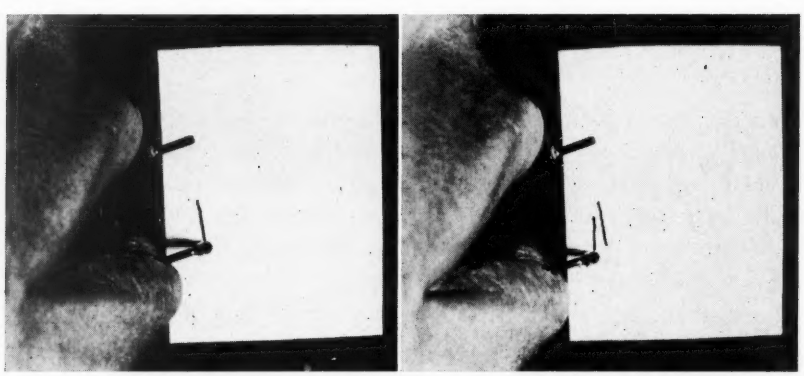


Fig. 1.—A deflective occlusal contact in centric occlusion exists when the mandible is in the terminal hinge position.

The position of the condyles is described in the definition of centric relation as ". . . the most posterior unstrained position in the glenoid fossae from which lateral movement can be made, at any given degree of jaw separation."[1] Once the neuromuscular pattern of closure which has been involuntarily developed by the patient to avoid trauma has been overcome, most patients can close the teeth readily to the first point of contact with the jaws in the terminal hinge position and they can repeatedly open and close the mouth while tapping one or more cusps in occlusion. Thus, there is not much of significance in the qualification, in the definition of centric relation, regarding the strained or unstrained aspects of this condylar relation. This first point of tooth contact can be easily located in most patients in a very few minutes. They will need no further help in closing the teeth into this relationship.

RELATIONSHIP TO DIAGNOSIS AND TREATMENT PLANNING

This concept of centric occlusion is directly related to diagnosis and treatment planning. The direction of the stresses to which the supporting structures are subjected during the functional movements of the mandible is of great importance.



A. *B.*

Fig. 2.—*A*, An eccentric closure is recorded on a card fixed to an upper appliance. *B*, A centric relation closure is recorded when the condyles are in terminal hinge position.

Whether or not these stresses are within physiologic limits determines whether the teeth are able to exist in their environment.

The results of stresses are directly related to the metabolic factors of the patient and are of paramount importance in the prognosis of the treatment. Vertical stresses are much more favorably received by teeth than are lateral and anteroposterior stresses. An analysis of the direction of stresses created when a patient closes the teeth into centric occlusion versus that with eccentric occlusion points to some very significant conclusions.

TEST PATIENT

Maxillary and mandibular appliances were constructed to record the centric and eccentric positions for a patient who was known to have deflective occlusal contacts when closing the teeth into centric occlusion. The appliances did not cover the occlusal surfaces, and they were rigidly attached to the teeth. The maxillary appliance supported a card on which a recording was made. The recording device was attached to the mandibular appliance.

The patient was instructed to open and close the mouth rapidly, striking the teeth together hard enough to be audible. A recordable pattern of centric or eccentric closure was produced. An eccentric closure, which is the acquired path of closure resulting from a neuromuscular phenomenon, was recorded (Fig. 2, *A*).

The next recording was obtained by manipulating the mandible into the terminal hinge position and then having the patient tap the teeth together. This recorded the path of closure to centric occlusion (Fig. 2, *B*), which was not an ideal cusp relationship. Instead, it was a deflective occlusal contact. The third recording involved the use of muscular stress by the patient to record the shift of the mandible from centric to eccentric occlusion (Fig. 3).

PATHOLOGIC WEAR OF TEETH

A reproduction of the three recordings is seen in Fig. 4. The direction of the stresses in eccentric closure results in varying degrees of pathologic wear of teeth.

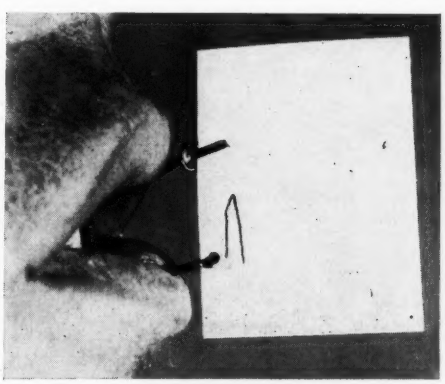


Fig. 3.—The shift of the mandible from centric occlusion to eccentric occlusion is observed extraorally on the tracing.

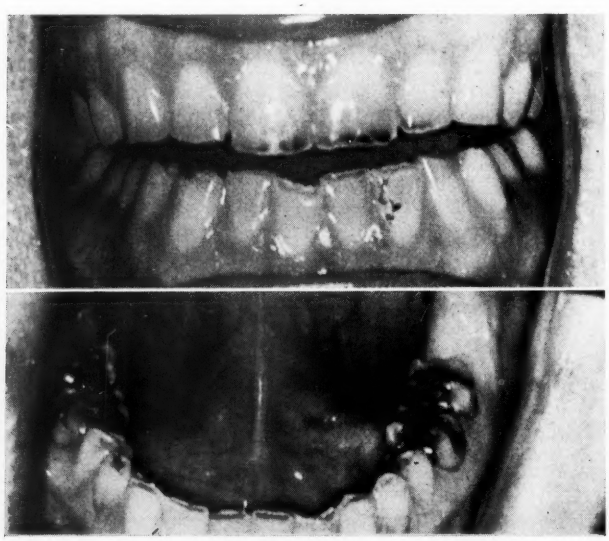
This eccentric closure results in a tooth-to-tooth contact that does not relate the anatomic parts of teeth as Nature intends; rather, it results in a destructive force to the cusps of teeth. This destructive force is probably most damaging during the

Fig. 4.—The three recorded mandibular closures: *(AB)* the eccentric closure; *(CD)* the terminal hinge closure; *(CA)* further closure from initial point of tooth contact at *C* to the terminal eccentric occlusion at *A*. The distance between *D* and *B* represents the retrusion of the mandible before closure. The line *CA* indicates the degree and direction of the eccentric closure.

chewing cycle when the mandibular path is from lateral to centric position. The existence of an eccentric occlusion results in an unharmonious cusp relationship which is not correlated with centric occlusion and condylar guidance.

Eccentric closure may cause excessive wear on the incisal edges of the anterior teeth with accompanying pathologic wear of the posterior cusps (Fig. 5). The early

A.



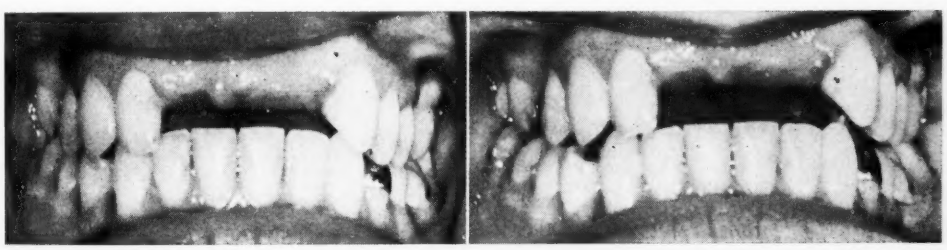
B.

Fig. 5.—*A*, Pathologic wear of *anterior* teeth may be caused by eccentric closure. *B*, Pathologic wear of *posterior* teeth may be caused by eccentric closure.

recognition of this condition and its correction are probably among the most important services that can be rendered to patients.

The prognosis of restorative procedures accomplished in an environment of eccentric occlusion is closely related to pathologic wear of teeth. A bridge (fixed partial denture) or an individual restoration receives very unfavorable stress, and when porcelain is used, frequent fractures result. Certainly, the abutment teeth of an anterior bridge receive unfavorable stress with destruction of the supporting structure because of an eccentric closure and stresses other than those in a vertical direction.

The diagnosis of centric occlusion and the development of a treatment plan on this fundamentally sound physiologic basis also result in restorative convenience (Fig. 6). The prognosis of any restorative procedure is greatly improved by occlusal equilibration and/or restoration to centric occlusion. Restoring a more nearly normal vertical and horizontal overlap removes the contact of the lower anterior teeth with the upper restorations and changes the direction of the stresses to which the restoration is subjected.



A. *B.*

Fig. 6.—The treatment plan is based on centric occlusion. *A*, The eccentric occlusion. *B*, The centric occlusion.

It is not unusual to hear a patient say that there is something wrong with the way his teeth come together. The patient in Fig. 1 sought dental treatment for this reason. He assumed that after his treatment he would be more comfortable, but when this did not follow, he sought further help. The restorations were made as individual units, after little or no diagnosis or treatment planning. The eccentric closure was overlooked or erroneously diagnosed. This did not provide the health service for which dentists are responsible.

RELATIONSHIP OF CENTRIC OCCLUSION AND INTEROCCLUSAL DISTANCE

There is a relationship between this concept of centric occlusion and the freeway space (interocclusal distance). The vertical dimension when the teeth are in centric occlusion must be within the physiologic limits that allow an adequate interocclusal distance after treatment.[3] Interocclusal distance measurements at the level of first tooth contact (point *C*, Fig. 4) in centric occlusion, therefore, determine the vertical dimension for the equilibration or restorative procedures.

With this concept of centric occlusion, a treatment plan based on a fundamental principle can be developed. This concept provides an exacting approach to diagnosis and treatment planning, not only for the clinical examination, but also in the transfer of casts to the articulator. The registration of centric occlusion is fundamental to all the other factors of occlusion. This concept of centric occlusion provides for a harmonious relationship of teeth during the functional movements of the mandible and insists that centric occlusion must be established first, before lateral movements can be reproduced or analyzed.

SUMMARY

The maxillomandibular tooth relationship when the mandible is in its terminal hinge position is fundamental in treatment planning. This tooth position is termed centric occlusion. Centric occlusion is fundamental to a study of the functional movements of the mandible and is related to all factors of occlusion. An analysis of the direction of stresses in centric closures versus that of eccentric closures discloses one of the important causes of pathologic wear of teeth and the resultant effect on the supporting structures. The objective is a treatment plan that restores harmonious cusp relationships within physiologic limits and one that is correlated with the condylar guidances.

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MAINTENANCE OF THE MAXILLOMANDIBULAR RELATIONSHIP DURING OCCLUSAL REHABILITATION

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THE MAINTENANCE of the desired maxillomandibular relationship during occlusal rehabilitation is one of the most difficult and perplexing problems in restorative dentistry. The prescribed maxillomandibular relationship must be maintained before, and particularly during, operative intervention when changes in the vertical dimension of occlusion and/or mandibular repositioning are indicated. When no changes in the maxillomandibular relationship are contemplated, but when carious and/or periodontal conditions dictate a full-coverage technique, the maintenance of the desired maxillomandibular relationship is of prime importance.

The greatest difficulty invariably ensues in transferring maxillomandibular relations to casts for the fabrication of corrective and restorative prostheses. The commonly used interocclusal records with their inherent shortcomings, accompanied by human error in the laboratory articulation of the master casts, give rise to frustrating and costly errors. Every dentist is aware of the unfortunate consequences of an increased or decreased interocclusal distance or centric occlusions which are functionally and anatomically incorrect.

MAXILLOMANDIBULAR RECORD DENTURE

The use of a simple restoration maintains the planned maxillomandibular relationship during both office and laboratory procedures for patients who have edentulous unilateral or bilateral free-end ridges. In addition, this restoration becomes a simple and automatic aid in achieving the impression for a removable partial denture in conjunction with a splinted fixed segment.[1]

Procedure.—In the simulated situations, only the six anterior teeth are present in the maxillary dental arch (Fig. 1). All of the natural teeth are present in the mandibular dental arch. Because of periodontal and/or carious involvement, the six maxillary teeth are to be splinted together by means of full-coverage restorations. A coil-spring attachment removable partial denture will be constructed to restore the missing teeth.[2,3]

Two simple acrylic resin, complete palatal-coverage removable partial dentures with clasps on the maxillary cuspids are constructed (Fig. 2). One of these dentures is used by the patient as a transitional temporary replacement. The other, after the occlusion has been balanced,[4] is used in all clinical and laboratory procedures as a maxillomandibular record.

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Fig. 1.

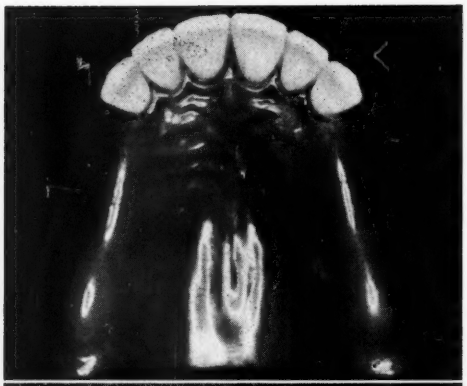

Fig. 2.

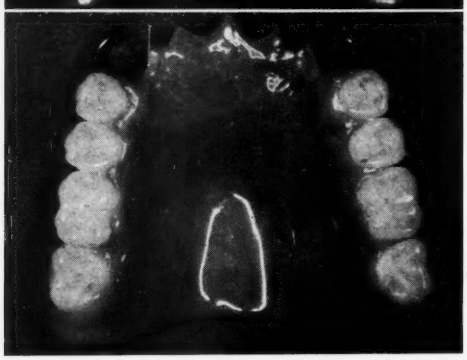

Fig. 1.—Because of periodontal and/or carious involvement, the six anterior teeth are to be splinted with full-coverage restorations. The missing posterior teeth will be replaced by a coil-spring attachment removable partial denture.

Fig. 2.—Two acrylic resin, complete-palate removable partial dentures with clasps for the cuspid teeth are made. One denture is used by the patient as a transitional temporary restoration, the other for clinical and laboratory procedures.

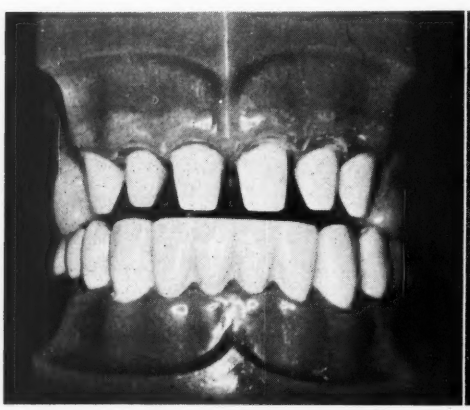

Fig. 3.

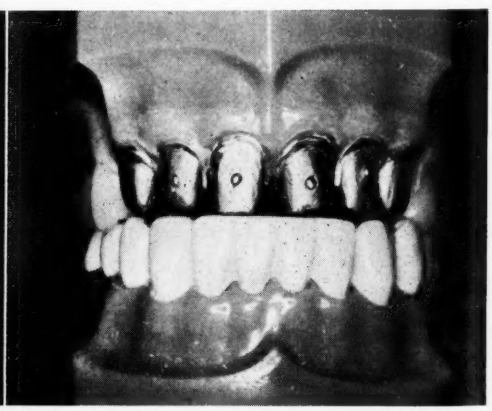

Fig. 4.

Fig. 3.—The maxillomandibular record denture serves as an interarch distance guide in the preparation of the anterior maxillary teeth.

Fig. 4.—The transfer copings and maxillomandibular record denture are in position in the (simulated) mouth.

The six maxillary anterior teeth are prepared for full-coverage restorations, using the maxillomandibular record denture as a guide during the preparation of the teeth. This denture, with the clasps removed (Fig. 3), serves as a positive record for the maintenance of the predetermined desired maxillomandibular relationship.

Impressions are made of the prepared teeth with modeling compound in copper bands or with elastic impression materials. Copper-plated mental dies are prepared and transfer copings are constructed. The transfer copings are placed on the prepared teeth, and the maxillomandibular record denture is inserted in the mouth (Fig. 4). A complete-arch plaster impression is made with the transfer copings and the maxillomandibular record denture in position (Fig. 5). A lubricant, such as liquid petrolatum, is used inside the transfer copings to facilitate their removal from the teeth.

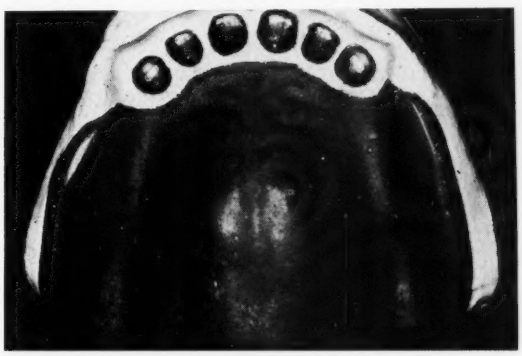

Fig. 5.—The over-all plaster impression contains the transfer copings and maxillomandibular record denture.

The copper-plated metal dies are placed into the transfer copings and a cast is poured. This cast (with the dies and the maxillomandibular record denture) is hand indexed by intercuspation with the mandibular cast (Fig. 6). In this way, the errors introduced by the use of interocclusal records of any material may be avoided. Gold veneer castings for the cuspids and gold thimble castings for the central and lateral incisors are made. The gold castings are fitted in the mouth with the aid of the same record denture.

Zinc oxide and eugenol impression paste is placed on the palatal surface of the maxillomandibular record denture to obtain an accurate reproduction of the edentulous areas and palatal tissues. The record denture is returned to the mouth, and an impression is made under moderate pressure with the teeth in centric occlusion and with all gold castings in position (Fig. 7). This impression serves as the final impression for the removable partial denture. An over-all plaster impression of the dental arch is made with the maxillomandibular record denture and the gold castings in position in the mouth.

Low-fusing metal is poured into the gold castings, and with the maxillomandibular record denture in position in the over-all plaster impression, a stone cast is poured. This cast is again hand indexed by intercuspation with the mandibular cast (Fig. 8).

Fig. 6.

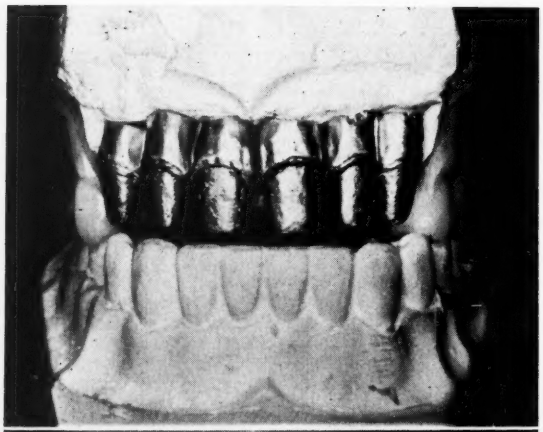

Fig. 7.

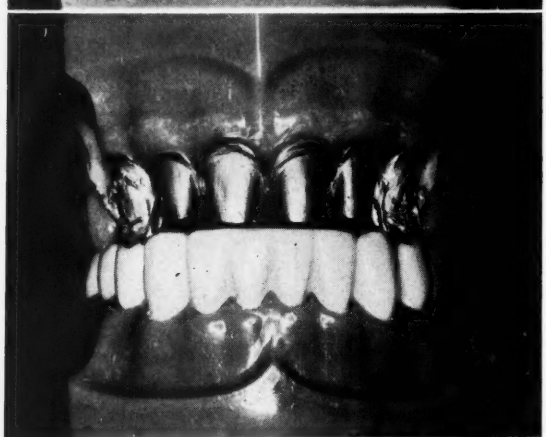

Fig. 8.

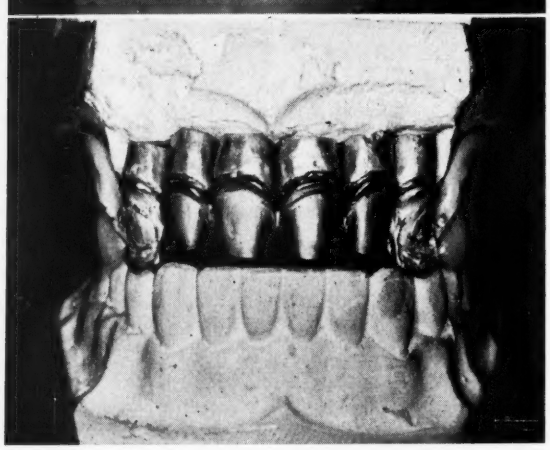

Fig. 6.—The maxillary cast, containing the copper-plated metal dies and the maxillomandibular record denture, is hand indexed by intercuspation with the mandibular cast.

Fig. 7.—A zinc oxide and eugenol impression is made in the maxillomandibular record denture with the teeth in centric occlusion. The gold castings for the anterior teeth remain in position in the (simulated) mouth.

Fig. 8.—The maxillary cast containing the gold castings for the anterior teeth and the maxillomandibular record denture with the paste impression are hand indexed by intercuspation with the mandibular cast.

Fig. 9.

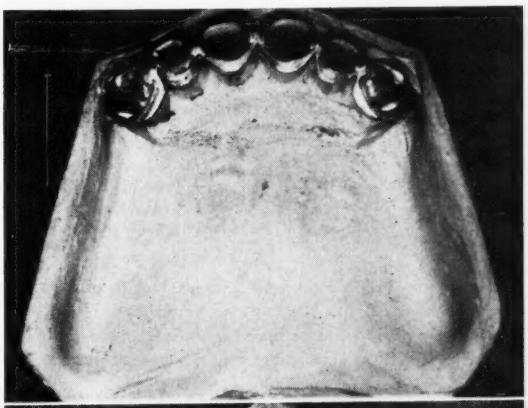

Fig. 10.

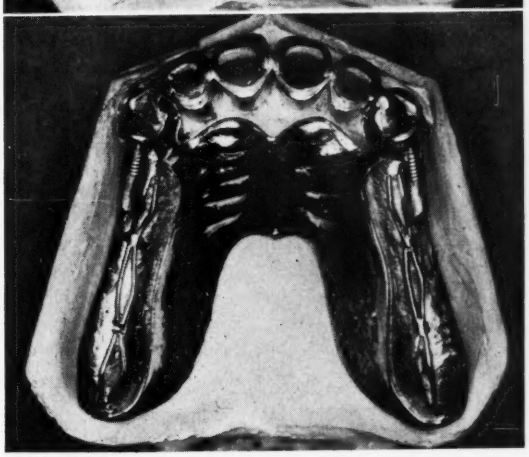

Fig. 9.—The maxillary cast, with the splinted anterior gold castings in place, is ready for the fabrication of the removable partial denture.

Fig. 10.—The framework of the coil-spring attachment removable partial denture is in place on the cast.

The gold castings are soldered together, tried in the mouth, and replaced on the articulated laboratory cast. After the maxillomandibular record denture (which contained the zinc oxide and eugenol paste impression) is removed, the metal framework of the coil-spring removable partial denture is constructed (Figs. 9 and 10). The removable partial denture framework with the teeth set up in wax is tried in the mouth together with the splinted six anterior gold castings.

Acrylic resin (or porcelain) is processed to the cuspid veneer castings, porcelain jacket crowns are constructed for the central and lateral incisors, and the coil-spring attachment removable partial denture is processed (Fig. 11). The completed units of the restorative prosthesis are inserted in the mouth and checked for functional occlusion, and the anterior splinted segment is cemented in the mouth.

The possibility for change in the desired maxillomandibular and occlusal relationship has been minimized (Fig. 12). At each stage of the procedure, the maxillo-

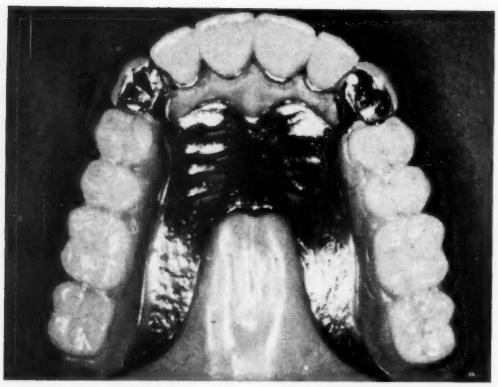

Fig. 11.—The completed restorative prostheses for the maxillary dental arch.

mandibular record denture was present as a positive record to maintain the desired relationship. When extensive edentulous areas exist in both dental arches, maxillomandibular "record" dentures are constructed for both arches.

Advantages.—The maxillomandibular record denture, which essentially is an acrylic resin, complete palatal-coverage removable partial denture, serves to (1) maintain the desired maxillomandibular relationship, (2) preserve the predetermined interarch distance, and (3) aid in making the impression for a removable partial denture.

Descriptive Terms.—In describing the maxillomandibular record denture, the terms "occlusal maintainer, interocclusal record, maxillomandibular maintainer, and centric maxillomandibular registration record" come to mind. None of these terms, however, are completely descriptive. Sears[5] discusses this related problem, and suggests the term "three-dimensional record (3-D record)." He defines this term as "the maxillomandibular record at the occluding relation." He further states, "It

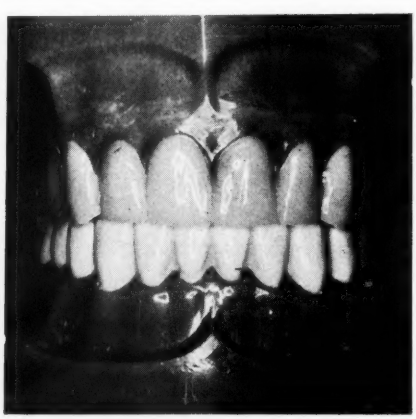

Fig. 12.—The completed maxillary restorations are inserted in the (simulated) mouth. The desired maxillomandibular relationship was preserved by the maxillomandibular record denture.

might, under some circumstances, be necessary to specify 'centric 3-D record' as we formerly sometimes said 'centric bite.' However, just as 'bite' ordinarily implies a record at centric jaw relation, so would '3-D record' unless otherwise indicated."

REFERENCE TRANSFER TABLE

A technique utilizing progressive sectional gold copings with acrylic resin reference tables is presented. This technique is useful for patients with a relatively full complement of teeth for whom a full-coverage procedure is indicated, with or without predetermined changes in the maxillomandibular relationship.

Procedure.—An alginate (irreversible hydrocolloid) impression is made of the entire mandibular dental arch prior to any preparation of the teeth. The mandibular left bicuspids and molars are prepared. Cold-curing acrylic resin is mixed and placed in the alginate impression in the region of the prepared teeth. The prepared teeth are lightly lubricated with petroleum jelly, and the alginate impression is accurately replaced in the mouth.

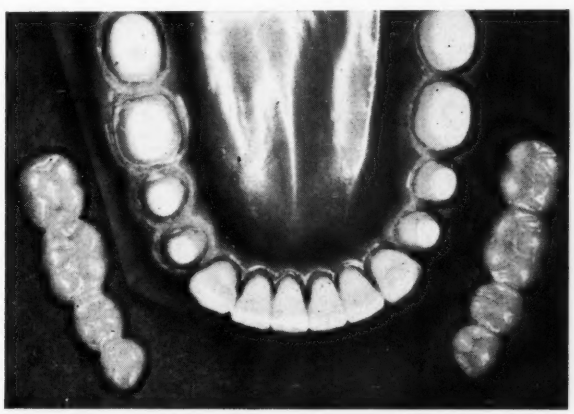

Fig. 13.—Cold-curing acrylic resin splints are constructed for the right and left mandibular bicuspids and molars.

After the acrylic resin has cured in the mouth, the alginate impression is removed and the excess is trimmed from the one-piece resin splint.[6] The splint is returned to the mouth, and the fit and occlusion are corrected. The splint is attached to the prepared teeth with a temporary cementing material, which will permit easy removal by the dentist. The splint now serves as a protective covering for the prepared teeth and also maintains the maxillomandibular relationship.

Prior to the preparation of the right mandibular bicuspid and molar teeth, another lower, complete-arch alginate impression is made. The teeth on the right side are prepared and the process is repeated for the construction of a one-piece acrylic resin splint (Fig. 13).

Individual modeling compound band impressions are made of all the prepared teeth, copper-plated metal dies are fabricated, and gold transfer copings are cast.

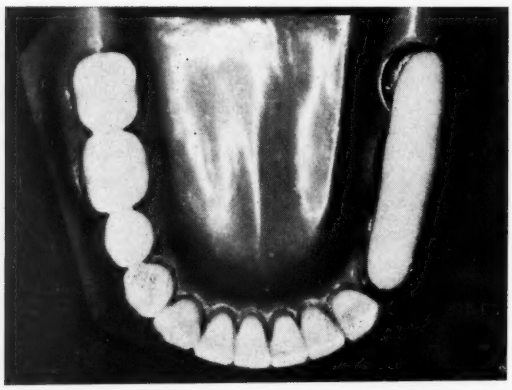

Fig. 14.—A mass of cold-curing acrylic resin is placed over the roughened occlusal surfaces of the transfer copings on one side. The acrylic resin splint remains in position on the opposite side.

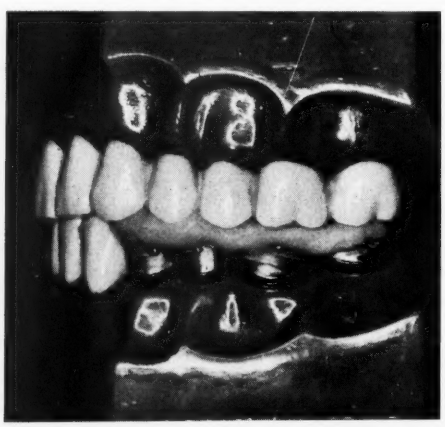

Fig. 15.—The patient closes the mouth in centric occlusion into the mass of cold-curing acrylic resin. The acrylic resin splint of the opposite segment serves as a guide and stop until the cold-curing acrylic resin has hardened in the mouth.

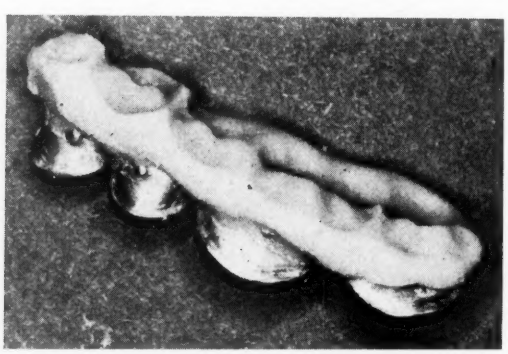

Fig. 16.—The reference transfer table. The cold-curing acrylic resin unites the transfer copings and registers the occlusal surfaces of the opposing teeth.

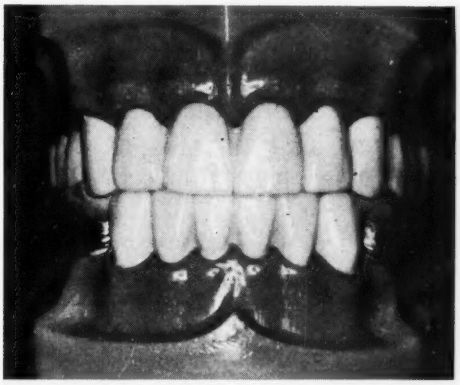

Fig. 17.—The right and left reference transfer tables are in the (simulated) mouth.

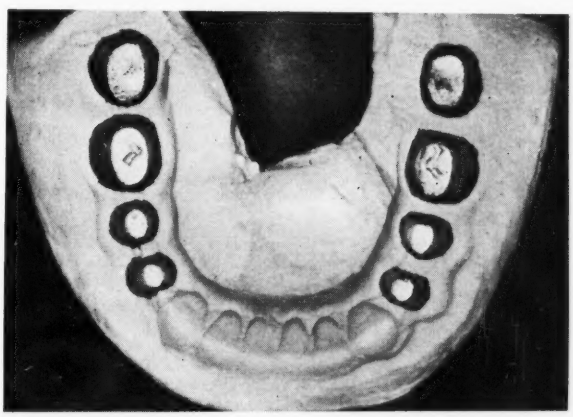

Fig. 18.—An over-all plaster impression of the mandibular dental arch is made with the reference transfer tables in position. Only the inside surfaces of the transfer copings are visible in the plaster impression. The cold-curing acrylic resin part of the reference transfer table is concealed inside the plaster.

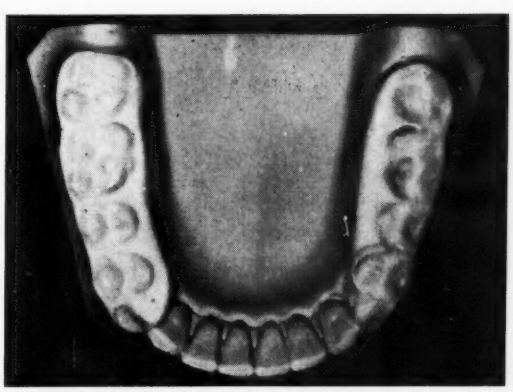

Fig. 19.—The reference transfer tables are in position (on the copper-plated metal dies) on the stone cast.

The transfer copings are placed on the prepared teeth of one side only. The acrylic resin splint remains on the opposite side to act as a temporary interarch distance record.

A mass of cold-curing acrylic resin is placed over the occlusal surfaces of the transfer copings (Fig. 14), and the patient is instructed to close the mouth into centric occlusion. The acrylic resin splint of the opposite segment serves as a guide and stop until the resin has cured (Fig. 15). The acrylic resin not only unites the bicuspid and molar transfer copings into one unit, but it registers the imprint of the occlusal surfaces of the opposing teeth. This entire unit is called a "reference transfer table" (Fig. 16).

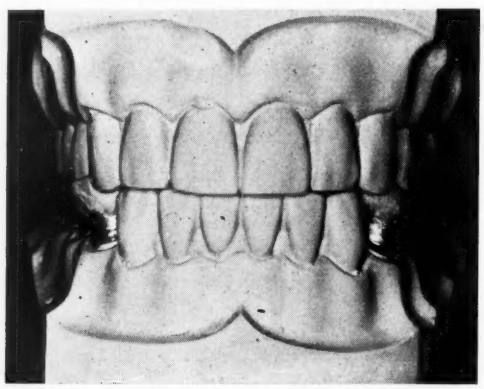

Fig. 20.—The maxillary cast is hand indexed into the occlusal imprints of the reference transfer tables on the mandibular cast. Then, both casts are mounted on an articulator.

This reference transfer table is left in position in the mouth while the same procedure is repeated for the fabrication of a reference transfer table for the opposite side. Thus, the reference transfer table for one segment serves as an occlusal index and guide for construction of the reference transfer table for the opposite side (Fig. 17).

With both reference transfer tables in position on the prepared mandibular teeth, an over-all plaster impression is made (Fig. 18). The copper-plated metal dies are placed in position in the transfer copings and a stone cast is poured. The cast contains the dies as well as the reference transfer tables when separated from the plaster impression. The position of the reference transfer tables is precisely the same on the cast as it was in the mouth (Fig. 19).

The maxillary cast is hand indexed into the occlusal imprints of the reference transfer tables, and both casts are mounted on an articulator. Thus, the exact duplication of the relationships in the mouth is available in the laboratory (Fig. 20).

In the fabrication of the restorations for one side of the mouth, the reference transfer table of the opposite side remains on the cast as an automatic stop, to prevent any discrepancy in the maxillomandibular relationship and the interarch distance. After the restorations for one side are constructed, they serve as a stop for the construction of the restorations for the opposite side. Thus, the use of reference

transfer tables has eliminated the need for reliance on wax or other easily distorted materials commonly used for interocclusal records. The restoration of the maxillary dental arch is completed by utilizing the reference transfer table technique. Thereby, the desired maxillomandibular relationship and interach distance are maintained.

SUMMARY

Two methods for maintaining the maxillomandibular relationship and interarch distance during occlusal rehabilitation have been described. The first method utilizes a maxillomandibular record denture when either unilateral or bilateral free-end edentulous ridges exist. This maxillomandibular record denture also serves as an aid in making the impression for a removable partial denture. The second method, a reference transfer table technique, is indicated when a relatively full complement of natural teeth is present.

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FIXED PARTIAL DENTURES BY ONE-PIECE CASTING

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THE CONSTRUCTION OF FIXED PARTIAL DENTURES is a tedious and time-consuming procedure for the patient, the dentist, and the prosthetic laboratory. At least ten stages are involved after the oral examination, diagnosis, and treatment plan have been completed.

This article describes a method which simplifies the construction of fixed partial dentures. Impression materials which require heat and cold are not used, and the use of the copper band as a tray is eliminated.[1,2]

ADVANTAGES

The one-piece casting fixed partial denture has many advantages. Some of these are that (1) a good fitting, comfortable temporary restoration is possible (see Fig. 8), (2) only one impression is made in an individual tray (Figs. 1 and 2), (3) the one-piece casting eliminates the soldering procedure (Figs. 3 and 4), (4) the restoration is completed in fewer appointments, (5) one impression is adequate for any number of restorations for the same jaw (Fig. 5), (6) no "settling" period is necessary before cementation, and (7) an accurate fit of the margins of the retainers to the abutment teeth is possible (Fig. 6).

PRELIMINARY INDIVIDUAL TRAY

The study cast of the jaw to be restored is duplicated. All undercuts on the duplicate cast are filled with wax and a spacer of one sheet of modeling wax is placed over the teeth and extended 3 to 4 mm. (Fig. 7). Three squares (2 by 2 mm.) are cut out of the spacer (not on teeth which are to serve as abutments). A tray of autopolymerizing acrylic resin is made on the prepared cast. The tray should be thick enough to be unflexible, and a handle is added to aid in making the impression (Fig. 5). The stops permit a predetermined amount of impression material between the surface of the tray and the tissues. The stops must be distributed so the tray can be stabilized. Undercuts are made around the border and on the inner surface of the tray to retain the impression material.

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TOOTH PREPARATION

All of the preparations for any number of fixed restorations in the same jaw are completed. The preparations are sprayed with a warm saline solution and dried with gauze. An impression of the entire arch is made with a polysulfide rubber-base impression material (Fig. 5). A wax interocclusal record is made, and the correct shade for the temporary restoration is selected. The prepared teeth are protected with gutta-percha, which is secured with a temporary and sedative cement. The gutta-percha dressing should not remain in the mouth longer than a few hours, in order to avoid possible damage to the periodontal tissues.

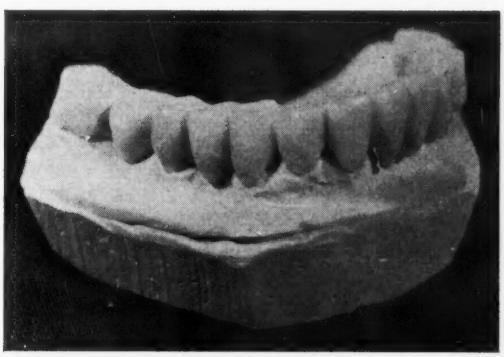

Fig. 1.—The temporary restoration is made of acrylic resin.

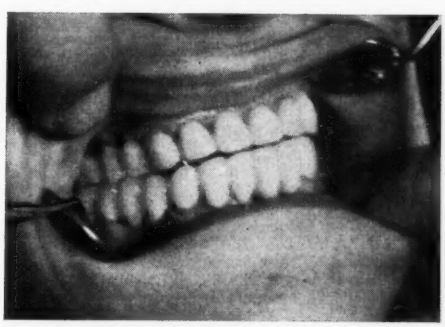

Fig. 2.—The temporary restoration is in place in the mouth.

TEMPORARY RESTORATION

Two casts are poured in artificial stone. One of the casts is mounted to the opposing cast by means of the interocclusal record, and the temporary restoration is carved, flasked, and cured in acrylic resin. Since the temporary restoration is made on a good impression, it fits well on the prepared teeth (Figs. 1 and 2), is strong, protects the teeth, is esthetically acceptable, is in good occlusion, and allows proper masticatory function. The temporary restoration is neither short of the margins of the preparations, nor does it impinge on the marginal gingivae or cut into the periodontal membrane.

FINAL INDIVIDUAL TRAY

The second cast is inspected for the correctness of the preparations. This cast is surveyed and all undercuts or other imperfections of the preparations are noted.

The individual tray for the final impression is made on this second cast. Because best results with polysulfide rubber-base impression material are obtained when the thickness of this material is about 1 mm.,[3] the cast, including the prepared teeth and the interdental spaces, is covered with a spacer 1 mm. thick (Fig. 8). Again, squares are cut in this spacer in strategic sites and a new tray is made of autopolymerizing acrylic resin. This tray should be as strong as the first one and also have a handle. The tray is made so that every prepared tooth is covered all around, including the interdental spaces. Thus, a uniform layer of impression material is assured over all surfaces of the prepared teeth (Fig. 5). The difference between the preliminary individual tray and the final one is that the final tray includes small individual trays for every preparation.

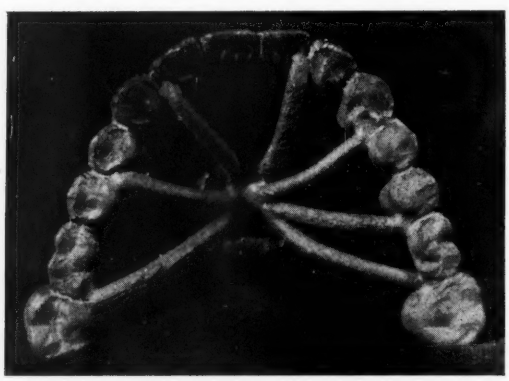

Fig. 3.—A one-piece casting is made for a complete jaw restoration.

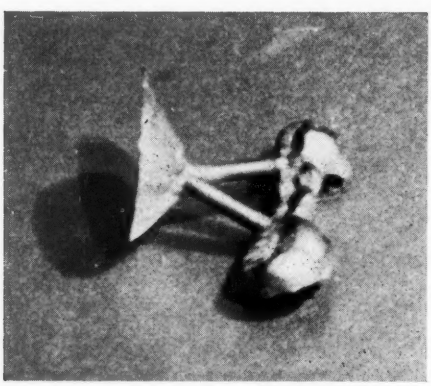

Fig. 4.—A small fixed partial denture is cast in one piece. Compare this casting with that seen in Fig. 3.

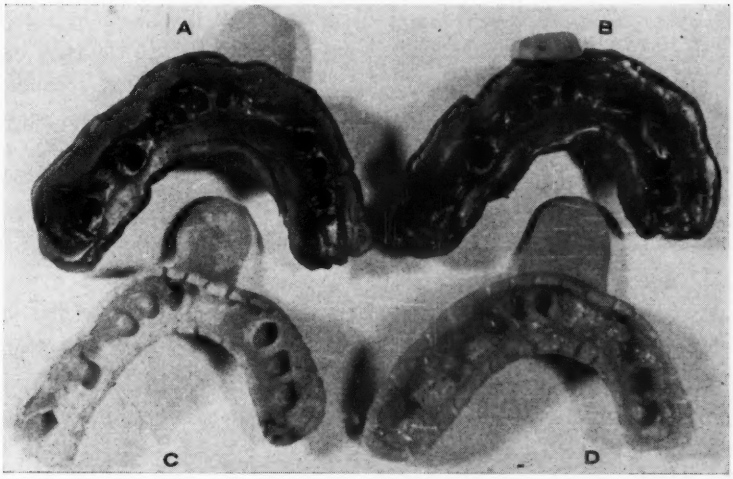

Fig. 5.—*D*, The preliminary individual tray is made of acrylic resin on the study cast. *B*, The preliminary impression after the preparation of the abutment teeth is made with a polysulfide rubber–base impression material. Two casts will be poured in this impression. One cast serves for the construction of the temporary restoration and the second cast is used for the construction of the final individual tray. *C*, The final individual tray. Note the difference of the preliminary tray *(D)*, and the final tray *(C)*. *A*, The final impression gives a sharp outline of the prepared teeth.

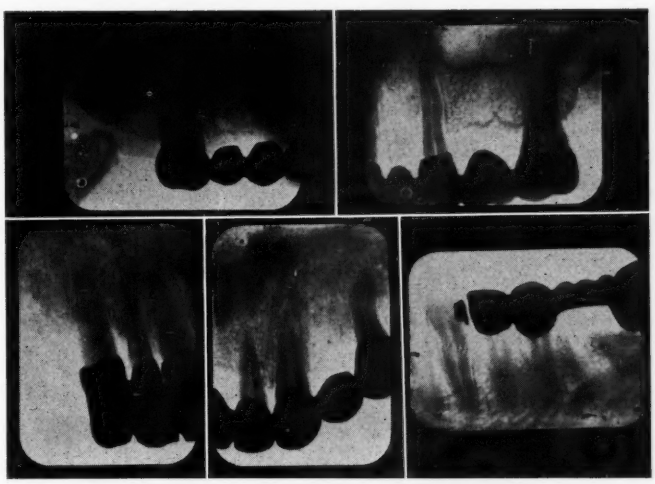

Fig. 6.—The roentgenograms indicate the perfect fit of the margins of the abutments to the abutment teeth.

FINAL IMPRESSION

If the survey has indicated that preparations must be corrected, the gutta-percha coverings are removed and the teeth are cleaned. The preparations are completed, and the final impression is made. If shoulder preparations are present, the sulci are packed for 2 to 3 minutes with a thread soaked in a 15 per cent zinc

chloride solution. A small mix of impression material is placed in the tray in the region of the prepared teeth. When the impression material in the tray begins to set slightly, a new mix of impression material is made and the tray is filled. The tray is inserted into the mouth, guided into place by the stops, and held long enough to allow the impression material to cure completely. The slight pressure of the thicker, partially set material pushes the thinner material into the gingival sulci around the prepared teeth. Upon removal, the impression is inspected, and if the smallest defect is discovered, the impression is remade. Sometimes, the impression material penetrates so deeply into the gingival sulci that it is necessary to remove these projecting parts before pouring the cast. If these thin pieces are not removed, they are pushed aside by the artificial stone, and an inaccurate cast may be produced.

A binder between the tray and the impression material is not used because (1) the tray has sufficient undercuts to hold the impression material securely in place, (2) thin layers of impression material cannot be discovered if a binder is used, and (3) the cured material can be removed easily from the tray if the impression procedure must be repeated.[4]

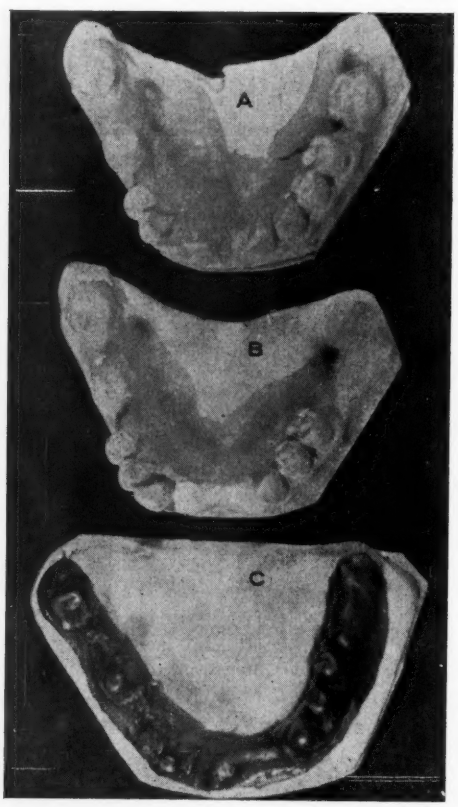

Fig. 7.—*A*, The study cast before extractions. *B*, A duplicate of the study cast with the teeth which are to be extracted removed. *C*, The wax spacer is on the cast prior to making the preliminary individual tray.

Fig. 8.—A 1 mm. thick wax spacer is applied on the cast for the fabrication of the final individual tray. Note the exactness with which this wax layer is applied.

A new interocclusal record is made and the shade of the final restoration is determined. The temporary restoration is cemented, the occlusion is balanced (Fig. 2), and the patient is dismissed until the final restoration is finished.

LABORATORY PROCEDURE

An artificial stone master cast is poured in the final impression. After the stone has set, the tray is cut into two or more sections before removing, so that delicate parts of the master cast will not be broken. This procedure should be followed especially when three-quarter crowns or inlays are incorporated in the restorations (Fig. 9).

A refractory cast is made from the master cast, and a duplicate cast (Fig. 10) is used to wax the abutment and pontic patterns (Fig. 11). The wax restorations are transferred onto the refractory cast, which is articulated so that the occlusion can be corrected. The margins of the wax restorations are sealed to the investment (refractory) cast, and unnecessary extensions of the cast are removed. The cast and pattern are invested, and the casting is made (Fig. 3).

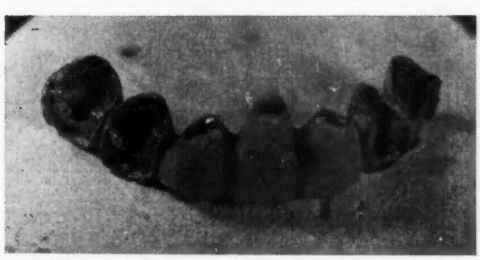

Fig. 9.—A restoration with four three-quarter veneer crowns and three pontics.

Fig. 10.—*A*, The refractory cast. *B*, The working cast for the same patient.

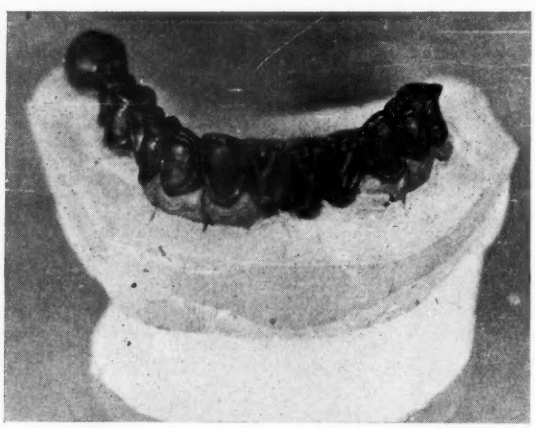

Fig. 11.—The abutments and pontics are waxed on the working cast.

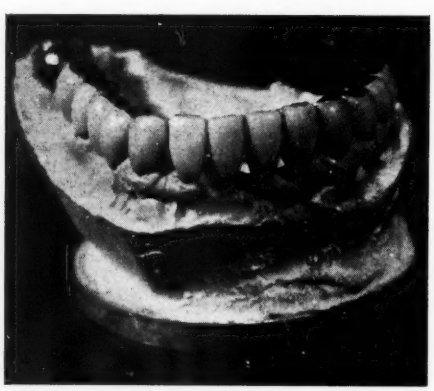

Fig. 12.—The completed restoration is on the master cast.

The gold casting is finished and the porcelain or acrylic resin facings are added to it. No "try-in" is necessary since the one-piece cast restoration goes into place with finger pressure only. The completed restoration is fastened onto the abutment teeth with either a temporary or permanent cement (Fig. 12).

ELIMINATION OF UNDESIRABLE PROCEDURES

The one-piece casting eliminates certain procedures in fixed partial denture construction that are injurious to the teeth and their surrounding tissues. The undesirable procedures are that (1) protection of the prepared vital teeth and soft tissue is inadequate, (2) the copper band cuts many fibers of the periodontal membrane,[1,2] (3) the heating and chilling of the modeling compound may cause permanent damage to the pulp of a prepared tooth, (4) the soldering procedure is a source of distortion[2,5-8] which may cause pressure and pull on the fibers of the periodontal membranes, (5) the electroforming is done on dies which are never as accurate as stone dies, and (6) dies positioned by means of transfers *never* have the same relationship to each other and to the other teeth as exist in the mouth. The correctness and parallelism of multiple preparations can be observed on a good cast which is produced from an over-all one-piece impression and inspected on a surveying instrument.

SUMMARY

A method of constructing a one-piece casting fixed partial denture has been described. The advantages of this method were presented. The results obtained from many of these restorations indicate that the procedure is dentally sound and is less time consuming for both the dentist and the patient.

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SEMIPERMANENT SPLINTING—AN ADJUNCT TO RESTORATIVE DENTISTRY

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THE PROBLEM OFTEN ARISES DURING REHABILITATION as to whether certain periodontally involved teeth should be removed. Frequently, the decision between including these questionable teeth in the restoration or extracting them is critical. It would be of valuable diagnostic aid if these teeth could be splinted temporarily to observe how they would respond.

Periodontists have utilized temporary fixation of loose teeth to stabilize them and improve the chance for repair, as well as to retard further breakdown caused by the mobility itself. Stabilization by means of stainless steel ligature wire or waxed silk has been employed. However, both the wire and silk ligatures are easily dislodged, need constant adjustment and tightening, and do not afford the amount of fixation that the loose teeth may require.

To obviate the problems of these temporary splints and to create fixation similar to that obtained by soldering a group of abutment castings, a rigid type of temporary splint was devised. The splint utilizes a stainless steel wire imbedded in cold-cure acrylic resin.[1]

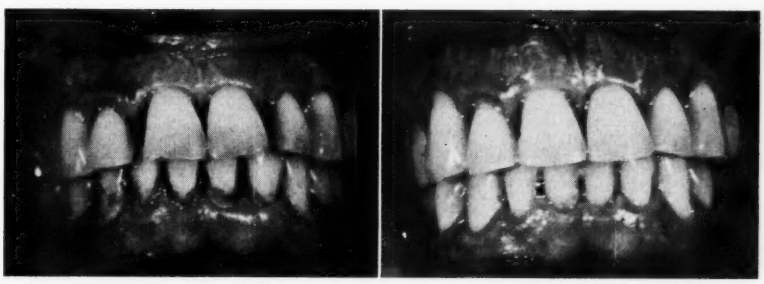
USES

Wire and acrylic resin splints have many practical uses in restorative dentistry, some of which are (1) to ascertain, by leaving a wire and resin splint in place for 6 months to 1 year, whether teeth should be maintained with a fixed permanent splint or extracted, (2) to prevent further drifting of teeth without the need for excessive tooth preparations for crowns (Figs. 1 and 2), (3) to prevent the early loss of the anterior teeth when the posterior teeth have been successfully restored by fixed prostheses (Fig. 3), (4) to accommodate to the situation in which ill-health or psychologic reasons prohibit subjection to the rigors of multiple preparations and/or extractions, and (5) to prevent the necessity for removal of an entire fixed restoration should a solder joint fail and cause a separation of the abutment teeth.

The precepts used in any fixation must be used for this procedure. Tying mobile teeth to other mobile teeth only permits all teeth to move as a segment. At least one firm tooth should be included on each end of the splint if possible. A premolar should be utilized when anterior teeth are splinted. Going around the curve of the dental arch aids greatly in stabilizing the anterior teeth against the forward thrust of the forces of occlusion.

TECHNIQUE

A channel, the width of a No. 559 bur and about 1.0 to 1.5 mm. deep, is prepared on the lingual surfaces of the teeth, close to, or preferably at, the contact areas. The channel is cut into the interproximal spaces, with care taken not to cut through to the labial surfaces of the teeth. It is dovetailed on the distal half of the terminal teeth. Both the gingival floor and the incisal walls of the channel are undercut with a small wheel bur. The interproximal spaces are prepared to simulate a class III cavity preparation and are undercut. A double strand of soft stainless



A. *B.*

Fig. 1.—*A*, Excessive movement of the teeth has been caused by faulty occlusion and periodontal disease. *B*, The teeth have been retracted orthodontically and the occlusion corrected. Upper and lower wire and acrylic resin splints are in position to stabilize the teeth.

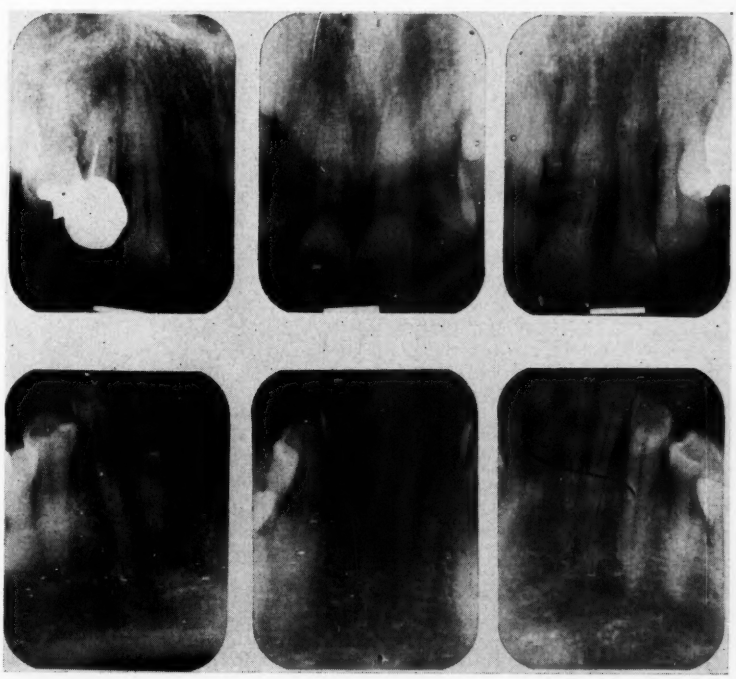


Fig. 2*A*.—Roentgenograms of the patient seen in Fig. 1, prior to treatment.

steel ligature wire (0.001 inch) is finely twisted and bent to lay against the pulpal floors of the preparations in the teeth. The wire is closely adapted into the interproximal preparations (Fig. 4).

A finely powdered, tooth shade autopolymerizing acrylic resin is applied in small quantities with a brush. The wire is covered and the resin is painted into all the undercuts. The application of acrylic resin is started at one terminal tooth. Small portions of the dry powder are picked up by the brush, moistened with monomer, and deposited in overlapping layers until the entire channel preparation is slightly overfilled. The resin is allowed to cure for 10 minutes under a coating of a diluted solution of aerosol and glycerine. This mixture prevents too rapid evaporation of the monomer and crusting of the plastic surface. When cured, the excess resin is trimmed away with stones and burs and the splint is polished. The occlusion is meticulously checked and corrected.

The amount of shrinkage of the acrylic resin can be controlled to a great degree by applying pinhead size portions with each brush application. The application of larger amounts of resin permits excessive shrinkage and causes loss of retention. It also becomes difficult to prevent the soft plastic from flowing beyond the margins of the preparations, which complicates the trimming and polishing.

DISCUSSION

These splints were designed originally to be used for relatively short periods of time. In many instances, however, 6 months to 1 year after insertion the splints

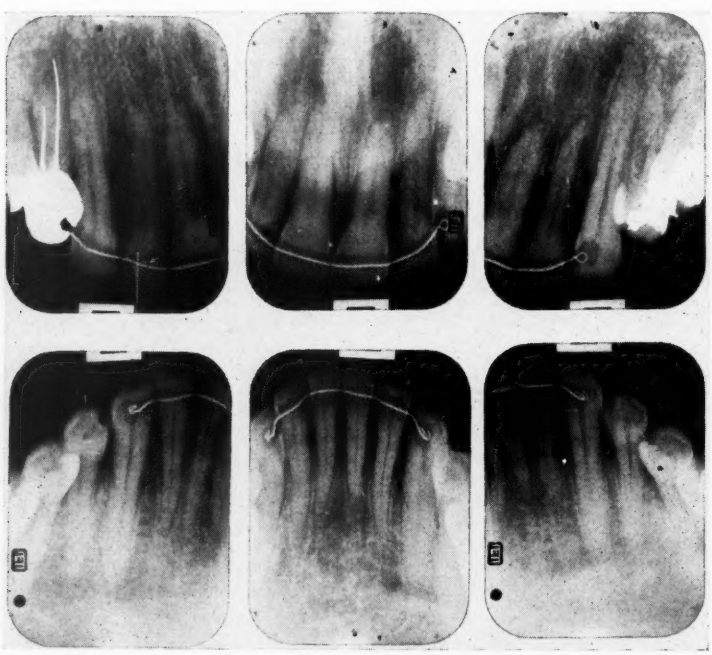


Fig. 2*B*.—The roentgenograms after treatment.

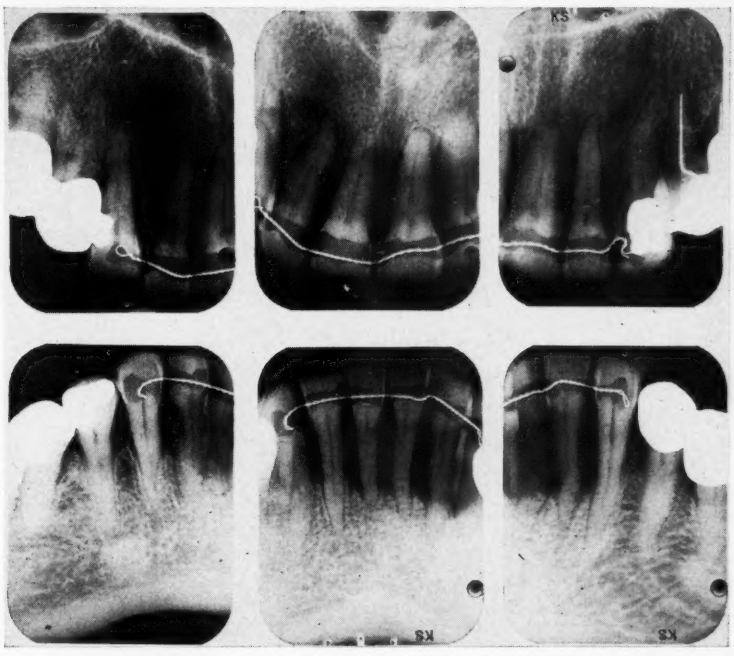
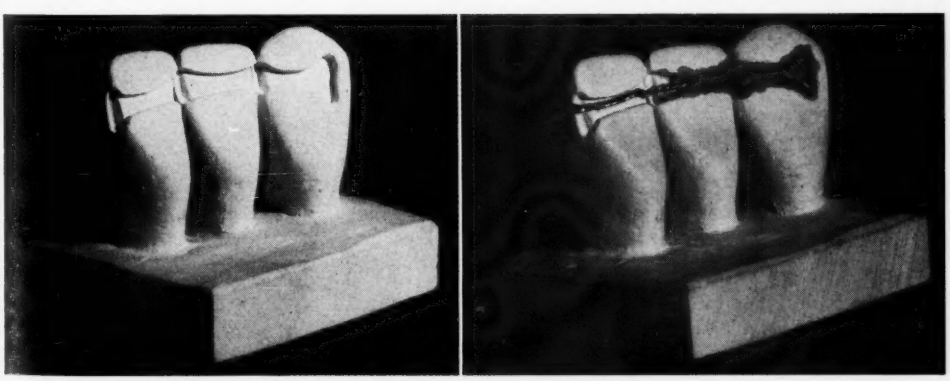


Fig. 3.—The wire and resin splints are used to maintain mobile anterior teeth in conjunction with satisfactory posterior fixed restorations. The roentgenograms were made 5 years after the placement of the splints.

were holding firmly, and it was decided to delay further interference to determine how long they would continue to function satisfactorily. No chewing restrictions were placed on the patients. Some splints have functioned for more than 7 years. It has been necessary to remake only two of thirty-eight splints. Caries was noted only in these two failures, in which cases a tooth had moved away from the acrylic



A. *B.*

Fig. 4.—*A*, The lingual surfaces of the lower anterior teeth are prepared for a wire and resin splint. *B*, The wire is in position, and the acrylic resin is partially applied.

resin bar because of poor retention. The bone picture has remained static for most patients, and although some bone loss has been noticed in a few patients, the progress of the degeneration has been notably retarded.

SUMMARY

These temporary or semipermanent fixed splints have many practical uses in restorative dentistry. If the preparations have sufficient internal retention and are extended to include fairly sound terminal teeth, the splints can serve for several years. This procedure delays the need for extractions and/or extensive tooth preparation and forestalls expensive and time-consuming dental rehabilitation. Wire and acrylic resin splints do not supplant fixed splints made of soldered castings but merely serve as an adequate temporary splinting method for certain patients.

REFERENCE

1. Obin, J. N., and Arvins, A. N.: The Use of Self-Curing Resin Splints for the Temporary Stabilization of Mobile Teeth Due to Periodontal Involvement, J.A.D.A. **42**:320-322, 1951.

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AN ESTHETIC ANTERIOR PINLAY SPLINT

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GROUP FIXATION OF MOBILE TEETH can be performed in a conservative two-appointment procedure. The technique entails multiple pinlays connected at the contact points in such a manner that maximal restoration of esthetic appearance results. This method eliminates the problem of pinlay impressions, separate fittings of each unit, and soldering of the multiple units.

PROCEDURE

Sufficient enamel to allow for a gold covering is removed from the entire lingual surface of the teeth to be splinted. Three pinholes are made in each tooth. Two of the holes are made just cervically to the incisal edge and the third hole is placed in the cingulum. All three holes must be parallel with each other. When the lower anterior teeth are narrow and overlapped, the protruding angles of the teeth should be ground to present a continuous incisal line. This will allow better access for placement of the pinholes.

A 5 to 7 mm. length of 18 gauge zephyr wire which has been tapered to a point by grinding at one end is placed in each hole. The wire pins must be parallel and fit snugly in the holes (Fig. 1).

All unground tooth surfaces and undercuts are eliminated with periodontal pack, gutta-percha, or zinc oxide and eugenol paste (Fig. 2). Then, free-flowing, cold-cure acrylic resin is carefully painted around the pins so that the exposed lingual surfaces of the teeth are covered. The resin is built up in several successive layers to attain a 2 to 3 mm. thickness. A curved reinforcement wire (paper clip) may be placed on the resin before it hardens. Additional resin is painted over the reinforcement wire to seal it to the splint. The resin is allowed to harden (Fig. 3).

The hardened acrylic resin splint, with the gold pins, is gently tapped and removed from the mouth. The reinforcement wire is ground off and the bulk of resin is reduced to minimize the amount of gold reduction which would be necessary later (Fig. 4).

Sprues are made in the acrylic resin splint, and it is invested, burned out, and cast in one piece (Fig. 5). Then, the cast gold splint is fitted to the preparations in the teeth. If the splint fails to go into place, pressure indicator wax is applied to the gold to indicate the location of the interference. The restoration is cemented to the teeth with oxyphosphate of zinc cement.

Fig. 1.

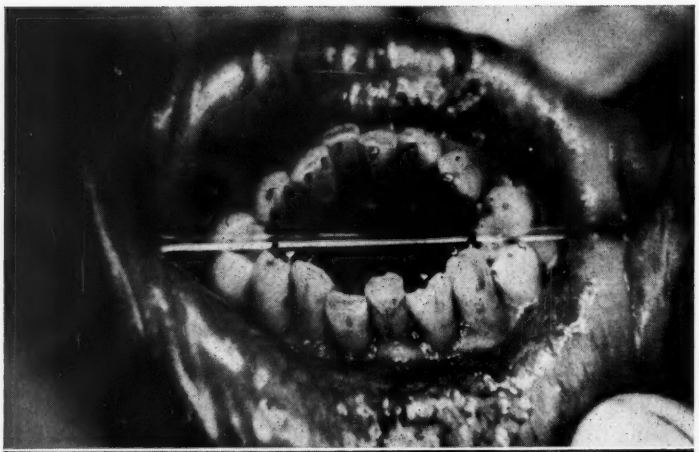

Fig. 2.

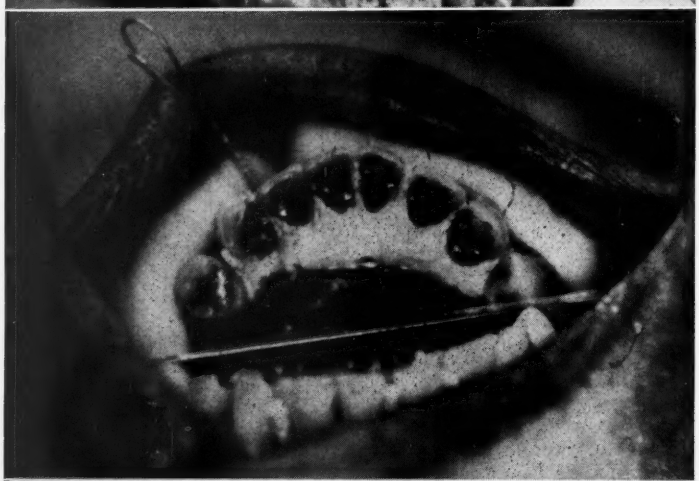

Fig. 3.

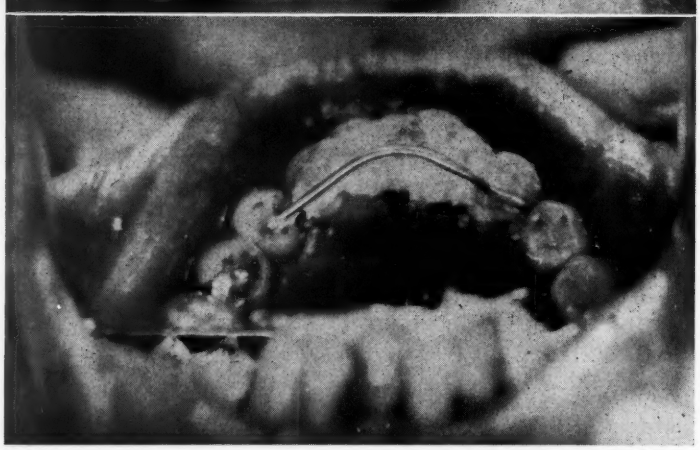

Fig. 1.—Tapered pins are placed in pinholes in the teeth after removal of the lingual enamel.

Fig. 2.—The undercuts are eliminated by means of a periodontal pack.

Fig. 3.—Acrylic resin is applied to the lingual surfaces of the teeth over the pins and a reinforcement wire is added to aid in the removal of the resin pattern.

ADVANTAGES

The advantages of this restoration are: (1) no gold is displayed, (2) the tooth reduction is conservative, (3) the procedure is not traumatic to the patient, (4) the operation requires a short time, (5) the laboratory procedures are simple,

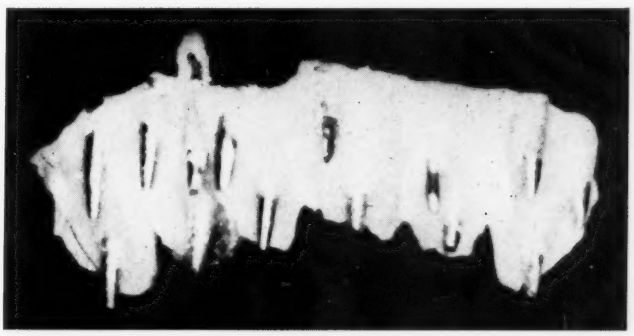

Fig. 4.—The bulk in the acrylic resin splint holding the gold pins is reduced and made ready for sprues.

Fig. 5.—The splint is cast in gold. Note the location of the sprues.

(6) missing teeth may be supplied on the splint by use of resin veneers on gold backings, (7) it can be used without removal of orthodontic retainers, and (8) it causes no tissue impingement.

DISADVANTAGE

The danger of interproximal caries is increased. The interproximal spaces must be properly brushed by the patient and should be examined periodically by the dentist.

SUMMARY

A two-appointment procedure for splinting multiple mobile teeth has been described. The advantages and disadvantage of this method were discussed.

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CROWNS

A PORCELAIN VENEER CROWN

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ACRYLIC RESINS are widely used as veneers for cast crowns. Even with cross-linked monomers and heat-treating procedures, however, the resins are still soft and subject to wear. They exhibit color changes in some mouths regardless of how well they are constructed. Furthermore, repairing worn or discolored veneers in the mouth is very unsatisfactory from an esthetic standpoint.

For these reasons I feel that the added effort required to construct a durable porcelain veneer crown is justified.

TECHNIQUE

An artificial tooth of the proper size, shape, and shade is selected from which is constructed a durable porcelain veneer which will compare favorably with resin esthetically and far outlast it. The artificial tooth is ground to fit the labial or buccal surface of the preparation. Two parallel flanges of porcelain extend into the mesial and distal interproximal spaces to give positive retention to the veneer (Fig. 1). The incisal angles of the porcelain facing must be obtuse to allow adequate bulk of gold for protection of the porcelain (Fig. 2). The incisal or occlusal edge of gold may then be feathered very thin to hide the gold and still provide adequate strength (Fig. 3). Porcelain is brittle and unyielding, and any pressure transmitted through thin or resilient gold will break or displace the facing.

The cut surfaces of the porcelain are smoothed and lubricated. The veneer is placed in the desired position on the preparation and the crown is waxed around it. Upon completion of the wax-up, a sprue is attached to the labial surface of the veneer with sticky wax and the veneer is removed from the wax boxing (Fig. 4). A sprue is added to the wax pattern, and the wax pattern is invested, burned out, and cast. The veneer is refitted into the casting, after any bubbles or turned edges of gold have been eliminated. The veneer cannot be forced into position without risk of breakage.

Read before the American Academy of Restorative Dentistry, Chicago, Ill.

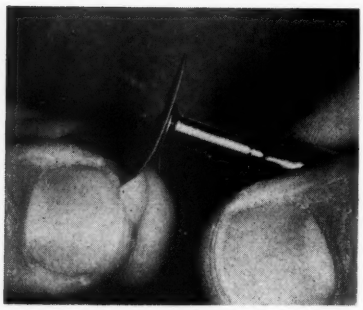

Fig. 1.—An artificial tooth is ground to fit the labial or buccal surface of the preparation. Note the extension that fits into the interproximal space to give retention to the veneer.

The crown is returned to the mouth and checked for accuracy of marginal fit and contact. When these requirements are satisfied, the facing is cemented into the casting with a cement which will not effect the shade of the veneer.

Often the labial or buccal contour of the veneer is not ideal. The correct contours can be established by grinding, with subsequent polishing or glazing (Fig. 5). The veneers may also be stained.

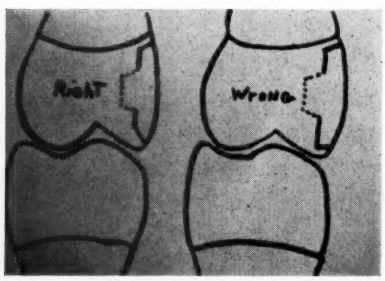

Fig. 2.—The incisal or occlusal angle of the porcelain veneer is prepared to allow ample gold for protection by means of an obtuse angle.

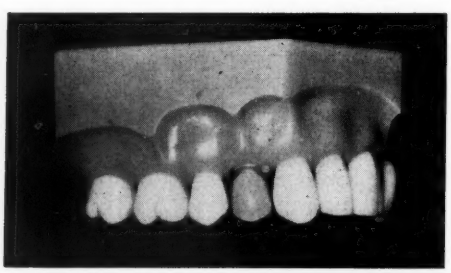

Fig. 3.—The gold is feathered on the occlusal surface so that esthetic appearance is not affected.

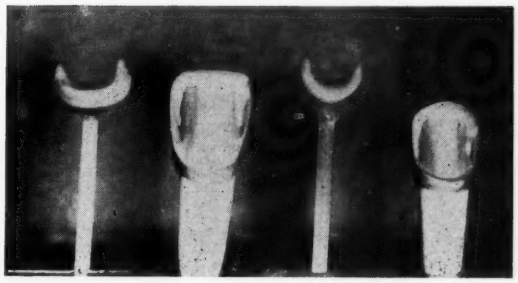

Fig. 4.—A sprue is added to the porcelain veneer and the veneer is removed from the waxed crown.

Fig. 5.—The contour of the veneer is corrected by reshaping the labial surface.

After cementation of the crown on the tooth, the gold may be beveled to reduce reflection of light. However, an adequate bulk of gold must be maintained to protect the facing against occlusal stresses (Fig. 6).

The two disadvantages of this technique are the difficulty in shading and the difficulty in hiding gold at the gingival margin; however, the advantages of durability of porcelain far outweigh these disadvantages.

Fig. 6.—The gold is beveled in the completed crown to prevent reflection.

CONCLUSION

Any veneer backed with gold is esthetically inferior to a porcelain jacket crown which in turn is inferior to healthy tooth enamel. We should be conservative in order to maintain healthy enamel surfaces whenever possible, but when we must use veneers and desire durability, the porcelain technique described offers a good solution.

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CONSTRUCTION OF CAST-GOLD CROWNS AND FIXED PARTIAL DENTURES BY USE OF GOLD BANDS

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A TECHNIQUE FOR MAKING single or multiple veneer and gold crowns in situations where copper tube impressions are difficult to make will be described. The procedure eliminates the use of tube impressions, dies, transfer copings, and casts for occlusal registrations. This method is of great value in making a crown directly in the mouth under a clasp of a removable partial denture.

The technique is shorter than gold plating copper bands for temporary fixed partial dentures, crowns, and splints. The results are more esthetic than gold-plated copper bands, for as the gold plating wears off, the copper bands become dark.

PREPARATION OF THE TOOTH AND THE GOLD BAND*

Prepare the tooth with a bevel shoulder slightly under the gingivae (Fig. 1). Select a gold band that fits the preparation snugly (Fig. 2). Contour the band and burnish the margins under the gingivae. Cut the band so it extends occlusally to a height of 2 mm. from the gingivae. Remove the band and serrate the incisal or occlusal margin.

Lubricate the preparation with petroleum jelly and remove the excess lubricant with a cotton roll. Replace, readapt, and burnish the band on the preparation (Fig. 3). Paint self-curing acrylic resin† between the band and the tooth and allow the resin to harden (Fig. 4).

Make bite-wing roentgenograms to check the gingival fit.

TECHNIQUE UTILIZING AN ELASTIC IMPRESSION MATERIAL

Make an irreversible hydrocolloid or rubber-base impression of the involved side of the dental arch before preparing the tooth (Fig. 5). Store the impression in a humidor.

Secure the band on the prepared tooth with self-curing acrylic resin painted on with the brush technique.

Fill the impression of the involved tooth in the irreversible hydrocolloid or rubber-base impression with acrylic resin, and seat the entire impression over the tooth and the previously adapted serrated band.

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*Zephyr gold band, 36 gauge, 3/16 inch wide; sizes according to copper band sizes. Ney Gold Co., Hartford, Conn.

†Fast-setting temporary acrylic resin, shade 21, Acrylite Co., New York, N. Y., or Jet Acrylic, shade 66, Lang Dental Mfg. Co., Chicago, Ill.

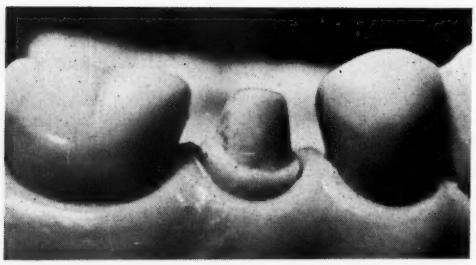

Fig. 1.—A bevel shoulder is placed slightly under the gingivae.

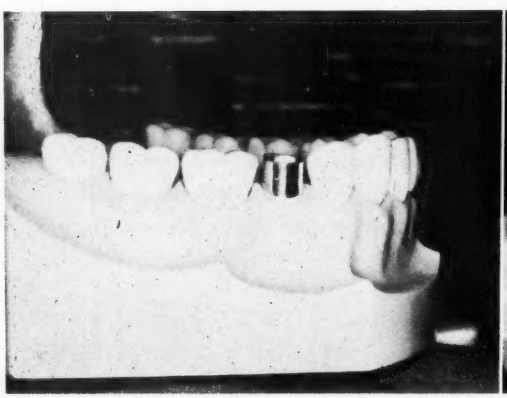

Fig. 2.

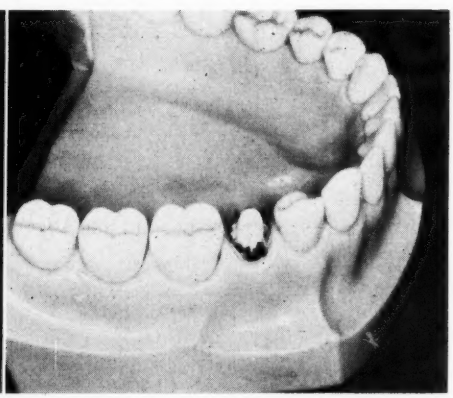

Fig. 3.

Fig. 2.—A 36 gauge, 3/16 inch wide gold band is fitted to the preparation.
Fig. 3.—The band is recontoured and burnished. Enough of the serrations are above the gingivae to engage the cold-curing acrylic resin.

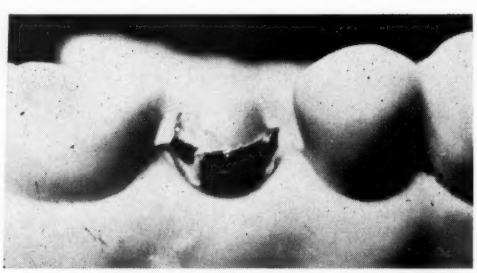

Fig. 4.—Cold-curing acrylic resin is painted between the band and the tooth and allowed to harden.

A splint can be made by filling the entire impression with acrylic resin. The bands are secured on the correspondingly prepared teeth as described.

When the acrylic resin cures, remove the crown from the tooth. Add acrylic resin where it is deficient, finish, and polish the crown (Fig. 6). If it is to be used for casting, remove any remaining impression material. If a sand blaster is available,

sand blast the crown thoroughly. Polish the crown with stones, sandpaper disks, and pumice. If the crown is to be used as a temporary restoration, polish it with whiting. If the gold crown is to be a cast veneer crown (Fig. 7), cut a space in it for the veneer.

GOLD BAND TECHNIQUE WITHOUT A PREVIOUS IMPRESSION

Make a mix of fast-curing acrylic resin and adapt it over the tooth with the band previously secured to the tooth by "painted-on" acrylic resin. Mold the resin with the fingers. If it is to be used for a splint, cover the part to be splinted with acrylic resin.

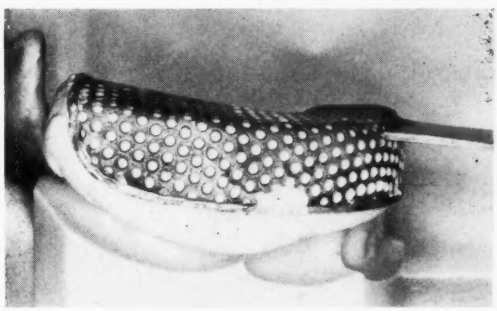

Fig. 5.—A rubber-base or irreversible hydrocolloid impression is made before the tooth is prepared.

Have the patient close the teeth into the soft acrylic resin, and remove the resin after it cures. Finish the crown or splint, and polish as described previously.

PREPARATION FOR A FULL VENEER CROWN

Cut the desired space for the veneer in the acrylic resin crown. Form an undercut edge around the veneer with a No. 14 wheel bur. Flow a thin film of wax over the face of the veneer and add bonding material* according to the manufacturer's instructions (Fig. 7).

It is advantageous to make a double check on the casting procedure. An alginate or rubber-base impression is made with the acrylic resin crown or splint in place. The cast is then poured in the following manner.

Block out any undercuts within the crowns with modeling clay. Push the crowns into a mound of impression plaster so that the plaster forms a matrix for the root of the die.

When the plaster has set, pour low-fusing die metal into the crowns imbedded in the plaster matrix. Break the plaster matrix and remove the crown and die. Trim the die root.

*Tentaform, Philadelphia Dental Co., Philadelphia, Pa.

Place the crown with the die back into the impression which was kept in a humidor. Secure the die to the impression tray with paper clips and sticky wax, and pour a stone cast. The master cast enables the dentist or laboratory technician to carve the veneer accurately and to check the next procedure, waxing the facing for the cast veneer crown.

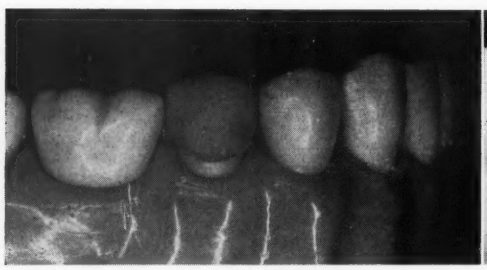

Fig. 6.

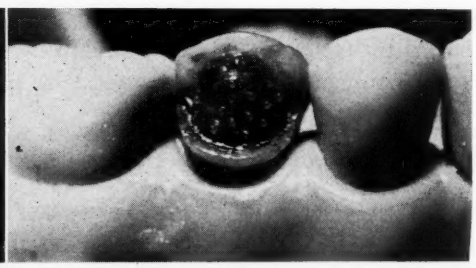

Fig. 7.

Fig. 6.—The gold band is covered with acrylic resin.
Fig. 7.—Space for the veneer is cut in the acrylic resin, and the bonding material is added to the resin.

CASTING PROCEDURES

The casting procedure differs slightly from the technique for wax patterns because of the physical properties of the acrylic resin after investing and during the burnout. The physical properties of acrylic resin that affect the casting are: (1) acrylic resin does not become as fluid as wax prior to its ignition and volatilization, (2) because of its density up to the point of ignition, the resin does not penetrate the investment as fluid wax does, (3) unless the acrylic resin is allowed to volatilize freely, internal pressure and turbulence are set up within the mold, and (4) hygroscopic expansion cannot be obtained because of the hardness of the acrylic resin.

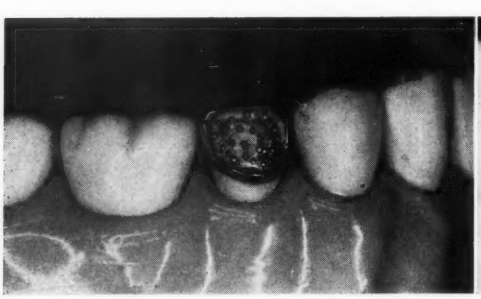

Fig. 8.

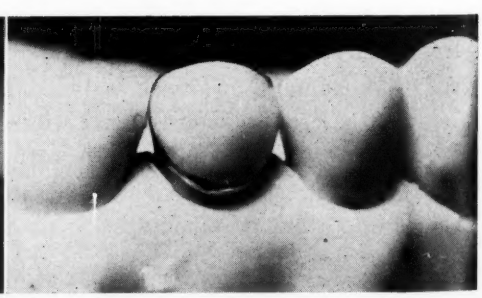

Fig. 9.

Fig. 8.—The completed casting shows the nobs of gold formed by the bonding material in the pattern.
Fig. 9.—The acrylic resin facing is heat cured on the crown.

The investment and burnout technique is completed as follows.

Line the casting rings with one layer of asbestos. Invest the pattern in a three-to-one mix of a nonoxidizing inlay investment.*

Allow the investment to set for 30 minutes and place the casting ring, with the sprue hole up, in a cold furnace. The sprue must be up to relieve internal pressure and turbulence and allow free volatilization of the resin.

Heat the furnace to 1,250° F. and maintain this temperature for 10 minutes. Cast the restoration using any desired casting technique (Figs. 8 and 9).

SUMMARY

A procedure is described which permits the appearance, fit, occlusion, and proximal contacts of crowns to be checked accurately prior to casting. This technique eliminates the complicated systems of recording jaw relationships and using copper-tube impressions and transfer copings. This method enables the dentist to carry out his own laboratory procedures satisfactorily.

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*Whip-Mix Beauty Cast, Whip-Mix Corp., Louisville, Ky.

TESTING LINERS UNDER CEMENTS IN VITRO

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THE NEED FOR A LINER under silicate and phosphate cements to protect the pulp against the injurious action of their acids is well established.[1,2] However, many liners have been placed upon the market after only a brief clinical trial. In general, uncontrolled clinical trials of new therapeutic agents tend to be subjective and nonquantitative and rarely detect pulpal damage, since damage to the pulp by the acids from cements usually does not become evident until 1 to 2 years later. The pulp may degenerate over a long period of time, without pain or any other symptom. Evidence of damage appears only when the tooth becomes dark or an acute periapical flare-up occurs.

The bioassay of the effects of filling materials on the pulp and of the protective action of various liners and bases can be accomplished more objectively and under much better controlled conditions in the teeth of animals, e.g., dog, monkey, or rat. However, even the bioassay method in animals is time consuming unless the manufacturer does the testing prior to placing his product on the market. In view of the large numbers and diverse nature of untested liners, there is a need for a simple and rapid testing method in vitro which would screen out the obviously inadequate liners. Such a method is presented and applied in this study.

METHODS

Glass tubes with an inside diameter of 7 mm. were filled with plaster of Paris into which was incorporated an acid-sensitive dye. This served as the "dentine model" to detect the penetration of the phosphoric acid. The glass tubes were empty local anesthetic containers and were approximately 77 mm. long.

Plaster of Paris (impression type) was mixed with a 0.04 per cent aqueous solution of bromcresol green (with pK at 4.7) or bromthymol blue (with pK at

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7).* The plaster mix was inserted into the glass tube and filled it to within 5 mm. of one end. The empty space within the tube (7 by 5 mm.) represented the cavity in the tooth (Fig. 1).

After the dyed plaster had thoroughly set, the test liner was applied to the plaster that formed the floor of the cavity and was allowed to dry. Free phosphoric acid liquid, silicate cement, or phosphate cement was then inserted into the cavity according to manufacturer's specifications. In the control series, the phosphoric acid, silicate cements, and phosphate cements were applied without an intermediary liner.

The dye gave a distinctly blue color to the plaster which turned white when the acid penetrated the plaster and reduced the pH below its pK value. The level at which the plaster changed color was used to indicate the depth of acid penetration (Fig. 1). The depth of penetration was recorded in millimeters at 2, 5, 15, 30, and 60 minutes and then at intervals of 3, 6, 9, 12, and 24 hours.

A minimum of twelve trials were run in each group. The results were not averaged, but the range of results is shown in the graphs.

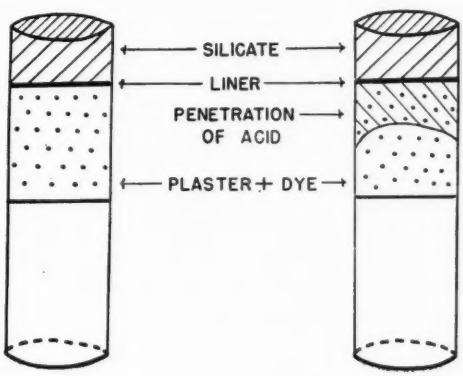

Fig. 1.—The method used to test the liners.

MATERIALS

A. Glass tubes 77 mm. long, open at both ends, with an inside diameter of 7 mm.

B. Plaster of Paris mixed with an acid-sensitive dye (0.04 per cent bromcresol green or bromthymol blue)

C. *Acid Sources.*—

1. Orthophosphoric acid (cement liquid) (S. S. White Dental Mfg. Co., Philadelphia, Pa.)
2. *Silicate cements:*
   a. S. S. White Filling Porcelain (S. S. White Dental Mfg. Co.]
   b. Durodent (Oskar Schaefer Co., Jersey City, N. J.)
   c. Petralit (Dental Fillings Ltd., London, England)

*pK = pH at which the dye changes color sharply.

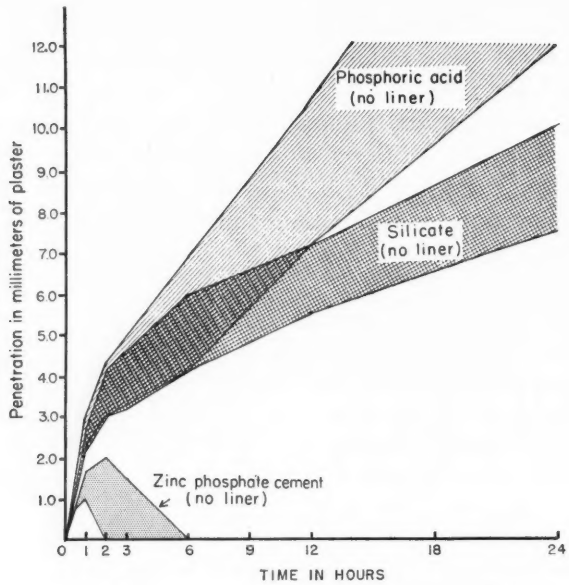

Fig. 2.—The graph shows the penetration of phosphoric acid liquid, acid from a silicate cement, and acid from a zinc phosphate cement through plaster containing 0.04 per cent bromcresol green dye indicator (pK 4.7); controls.

3. *Phosphate cements:*
   a. Zinc phosphate cement (S. S. White Dental Mfg. Co.)
   b. Black copper cement (The L. D. Caulk Co., Milford, Del.)
   c. Red copper cement (S. S. White Dental Mfg. Co.)
   d. A B C cement (Oskar Schaefer Co.)

D. *Liners Used.*—
1. Zinc oxide and eugenol with zinc acetate accelerator
2. Cavitec (Kerr Manufacturing Co., Detroit, Mich.)
3. Zinc oxide and eugenol paste (reagent grade powder)
4. Epoxy resin (Shell Chemical Corp., New York, N. Y.)
5. Silicone (Siliclad, Clay-Adams, Inc., New York, N. Y.)
6. Chembar (The L. D. Caulk Co.)[3]
7. Copalite (H. J. Bosworth Co., Chicago, Ill.)
8. Kal-Drox (American Consolidated Mfg. Co., Philadelphia, Pa.)
9. Pulpdent Liquid (Rower Dental Mfg. Corp., Boston, Mass.)
10. Pulpdent Paste (Rower Dental Mfg. Corp.)[4]
11. Calcium hydroxide paste (reagent grade mixed with distilled water)

FINDINGS WITH BROMCRESOL GREEN INDICATOR

The first series of tests were made with bromcresol green as the indicator. This dye has a pK at 4.7 and was selected because a pH of 4.7 is generally accepted as injurious to the enamel, dentine, and pulp.

Penetration in Unlined Specimens.—

Phosphoric acid liquid: When phosphoric acid liquid was placed into the cavity without any liner, the liquid penetrated rapidly and continuously into the dye-impregnated plaster. The penetration was rapid during the first 1 to 2 hours and thereafter almost as rapid (Fig. 2).

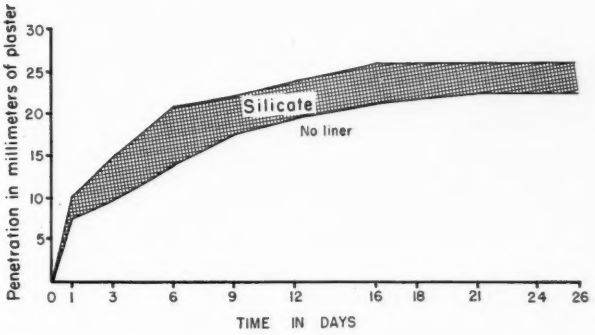

Fig. 3.—The penetration of acid from a silicate cement using bromcresol green dye indicator (pK 4.7).

Silicate cement: The acid from the silicate cement (S. S. White) placed into the cavity with no liner penetrated into the plaster almost as rapidly as the phosphoric acid liquid during the first 48 hours (Fig. 2). The rate of penetration decreased slightly thereafter but continued to progress rapidly for the next 6 days (Fig. 3). The rate of penetration slowed down from the sixth to the sixteenth day

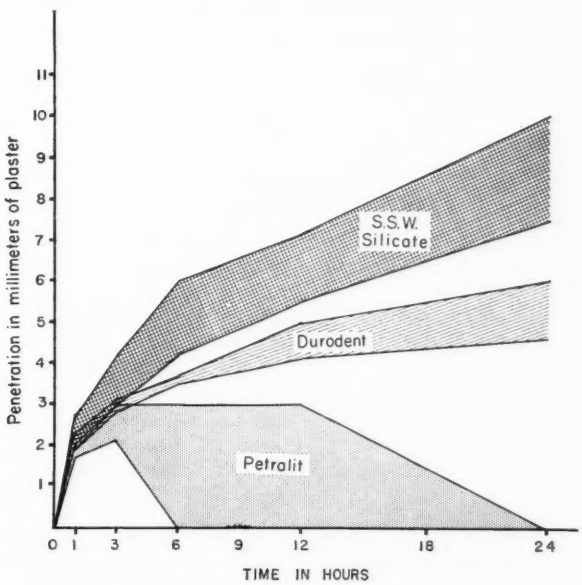

Fig. 4.—The graph compares the penetration of acid from three different silicate cements (bromcresol green dye, 0.04 per cent, pK 4.7).

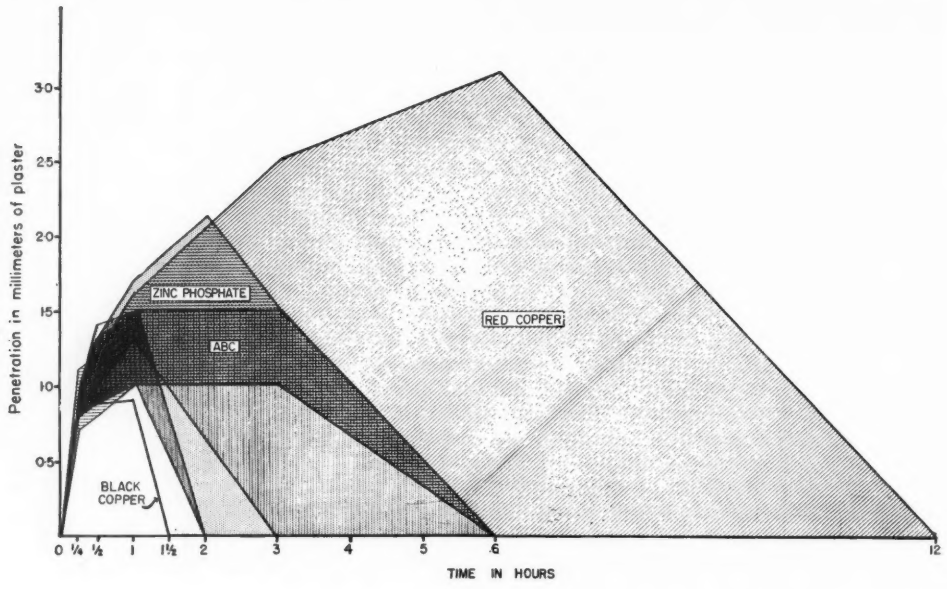

Fig. 5.—The graph compares the penetration of acid from different phosphate cements using bromcresol green dye (pK 4.7).

and formed a plateau showing no deeper penetration after the sixteenth day. There was no return of the blue color, however, which indicates that there was no drop in the pH below 4.7 during the entire period of 26 days of observations (Fig. 3). This supports the findings of Harvey, LeBrocq, and Rakowski[5] that the acid from silicate cements is released from the silicate gel continuously over a long period of time (at least 30 days) and that the release of the acid does not stop with the setting of the silicate cement. *Thus, there is a need for a protective liner under all silicate cements.*

Comparison of three silicate cements: The S. S. White Filling Porcelain showed the highest content of free phosphoric acid (Fig. 4). Durodent cement showed the same amount of free acid present during the first 3 hours but less than the Filling Porcelain thereafter. However, Durodent showed the typical course for a silicate cement (a parabolic curve with a plateau but no return to zero).

Petralit also showed a rapid release of free phosphoric acid during the first 3 hours but showed a return of the blue color after 6 to 24 hours. This indicated a neutralization of the acid below pH 4.7 in 6 to 24 hours. Since this reaction is typical of the behavior of the phosphate cements, it suggested that Petralit is a mixture of silicate and zinc phosphate cements.

Phosphate cements: Penetration of the phosphoric acid from a typical phosphate cement is shown in Fig. 2. Penetration was much less rapid (1 mm. in the first hour) than from a typical silicate cement (3 mm. in the first hour). The duration of penetration was also much shorter, from 1 to 3 hours in contrast to 16 to 21 days under silicates. Furthermore, after 1 to 3 hours, there was a rapid return of the blue color of the plaster, indicating a rapid neutralization of the acid and

a rise in the pH above 4.7 in 2 to 6 hours. However, these experiments show that free acid is present in a phosphate cement below a pH level of 4.7 for a considerable period of time (2 to 6 hours) *after the phosphate cement has set.*

The curve for phosphate cements was typically a closed one in contrast to the open plateau for silicate cements because a true chemical combination occurs between the zinc oxide powder and the phosphoric acid liquid, binding and neutralizing the liquid. The reaction of the silicate powder and the same phosphoric acid liquid produces a silicate gel within which free acid can exist for a much longer period of time.

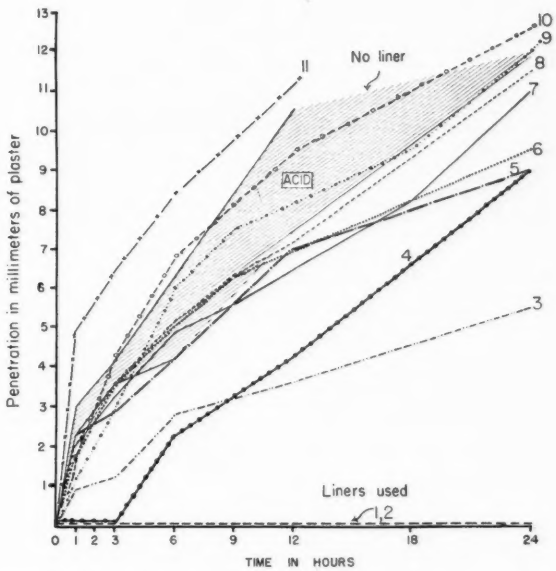

Fig. 6.—The graph shows the ineffectiveness of most liners when placed under phosphoric acid liquid (bromcresol green dye indicator, pK 4.7).

Comparison of different phosphate cements: The characteristic penetration curves of four popular phosphate cements are shown in Fig. 5. The red copper cement showed much deeper penetration (up to 3 mm.) than the other cements. Free acid was present below pH 4.7 for 3 to 6 hours (compared to the 1 to 2 hours of a zinc phosphate cement), requiring 6 to 12 hours to drop below pH 4.7 (compared to 2 to 6 hours). Black copper cement showed the least penetration of acid with a peak at ½ to 1 hour and dropping below pH 4.7 in 1½ to 2 hours. A B C cement closely followed the curve of penetration and neutralization shown by a typical zinc phosphate cement in spite of the claims of its manufacturer.

Effectiveness of Liners.—

Under phosphoric acid liquid: Each liner was placed under a pool of free phosphoric acid liquid for the most severe test. Only liners No. 1 (zinc oxide and eugenol with zinc acetate accelerator) and No. 2 (Cavitec) effectively resisted penetration by the acid under the conditions of this test for a period of 24 hours

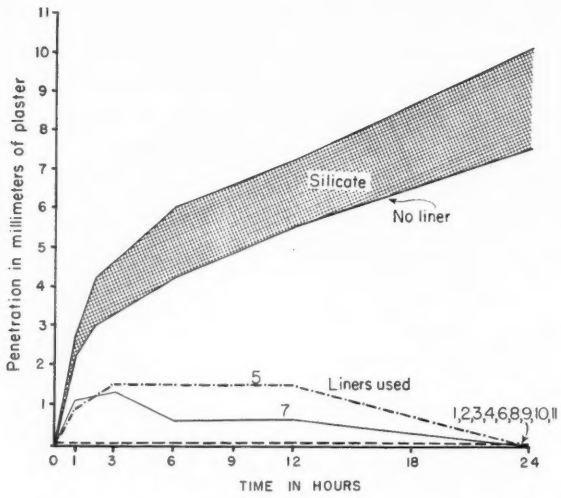

Fig. 7.—The graph shows the effectiveness of most liners when placed under silicate cement (bromcresol green dye indicator, pK 4.7).

(Fig. 6). Both were zinc oxide and eugenol preparations with accelerators added. Liners No. 3 (zinc oxide and eugenol paste) and No. 4 (an epoxy resin) stood up from 1 to 3 hours before "breaking." All other liners were quickly penetrated by the acid under these conditions (Fig. 6).

The results of these tests are shown as "average" lines rather than as ranges to simplify the presentation of data in graphic form.

Under silicate cement: S. S. White Filling Porcelain was used to test the effectiveness of each liner under a typical silicate cement. All liners stood up well

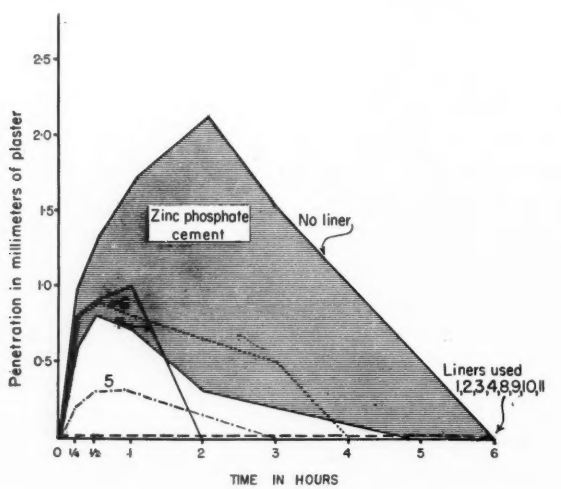

Fig. 8.—The graph shows the effectiveness of most liners when placed under a zinc phosphate cement (bromcresol green dye indicator, pK 4.7).

and resisted acid penetration under this silicate cement (Fig. 7). The free phosphoric acid liquid overwhelms the liners by the sheer quantity of acid present. The acid in the silicate cement is released in much smaller quantities from the silicate gel.

Liners No. 5 (a silicone) and No. 7 (a copal resin varnish) were significantly less effective than the other nine liners tested. The tendency of the silicate cement to become deeply discolored by the eugenol when placed over a zinc oxide and eugenol base was quite evident during the tests.

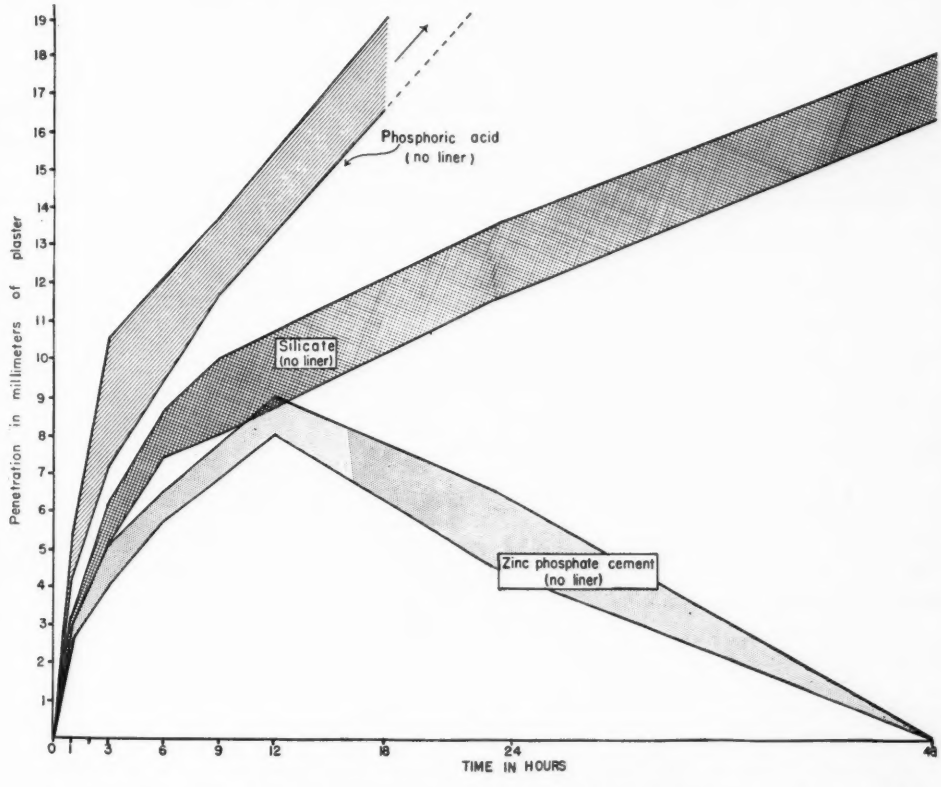

Fig. 9.—The graph shows the penetration of phosphoric acid liquid, acid from a silicate cement, and acid from a phosphate cement through plaster containing 0.04 per cent bromthymol blue dye indicator (pK 7); controls.

Under zinc phosphate cement: S. S. White zinc phosphate cement was used as the typical phosphate cement to test the effectiveness of liners in this series. All liners were effective in preventing the penetration of the acid from this phosphate cement with the exception of No. 6 (Chembar, a calcium hydroxide–polystyrene combination), No. 7 (a copal resin varnish), and possibly No. 5 (a silicone) (Fig. 8). Chembar behaved in a rather erratic fashion. The film broke and cracked unless great care was taken in its application. At least three coats were necessary to produce an intact film, since the first coat almost always shrank from the glass walls or cracked in the center.

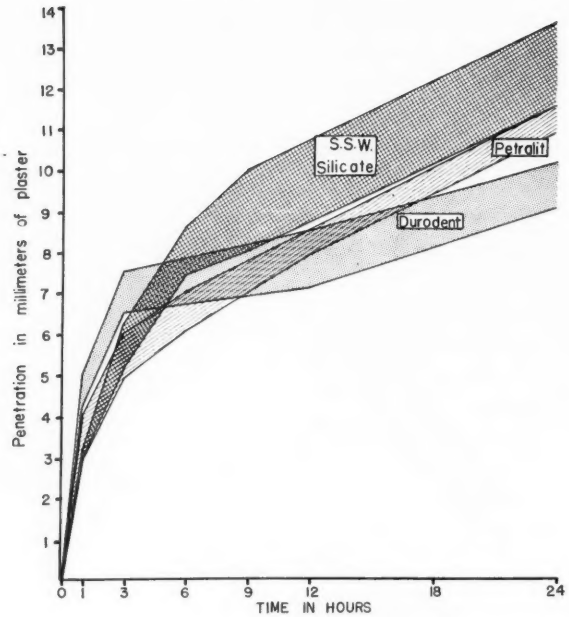

Fig. 10.—The graph shows the penetration of acid from three different silicate cements using bromthymol blue indicator (pK 7).

FINDINGS WITH BROMTHYMOL BLUE INDICATOR

The entire series of tests was repeated using bromthymol blue as the acid indicator. This dye has pK at 7 and thus indicates the condition of neutrality in contrast to bromcresol green which has pK at 4.7 and thus indicates the level at which the acid is most likely to be injurious to the enamel, dentine, and pulp.

The methods and materials in both series were otherwise identical.

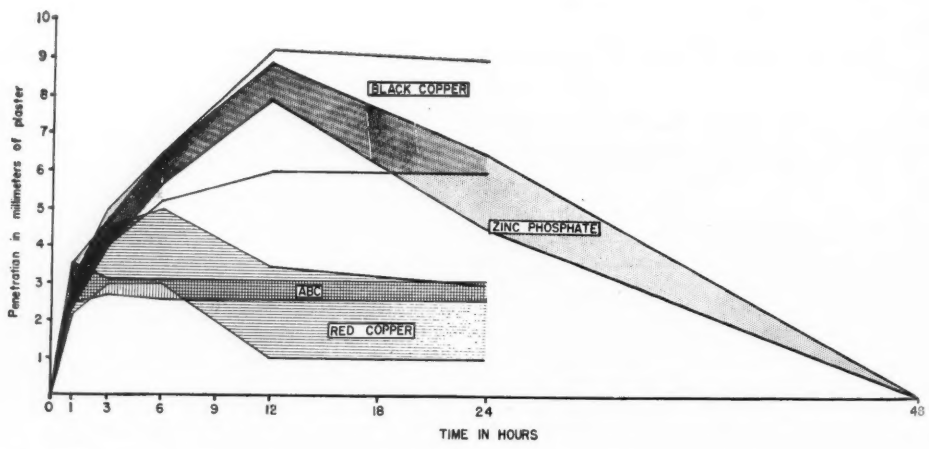

Fig. 11.—The graph shows the penetration of acid from four different phosphate cements using bromthymol blue indicator (pK 7).

Penetration in Unlined Specimens.—The curves shown in Fig. 9 are similar to those in Fig. 2 with the ordinate and abcissa considerably elongated. Bromthymol blue indicated a much more rapid and deeper penetration of the acid over a longer period of time from each of the three substances used. The character of each comparable curve is very similar. Comparison between Fig. 2 and Fig. 9 shows that the pH of the plaster under the zinc phosphate cement rose above 4.7 in 2 to 6 hours but did not achieve neutrality for 48 hours.

There was little difference in the behavior of S. S. White Filling Porcelain, Durodent, and Petralit when bromthymol blue was used as the indicator (Fig. 10). With this dye, Petralit behaved like a typical silicate cement.

The typical curves of four phosphate cements are seen in Fig. 11. Comparison with Fig. 5 shows that the black copper and the red copper cements had reversed their positions.

Effectiveness of Liners.—Again only liners Nos. 1 and 2 were effective in preventing the penetration of free phosphoric acid liquid over a period of 24 hours (Fig. 12). Liner No. 3 (zinc oxide and eugenol paste) was partially effective.

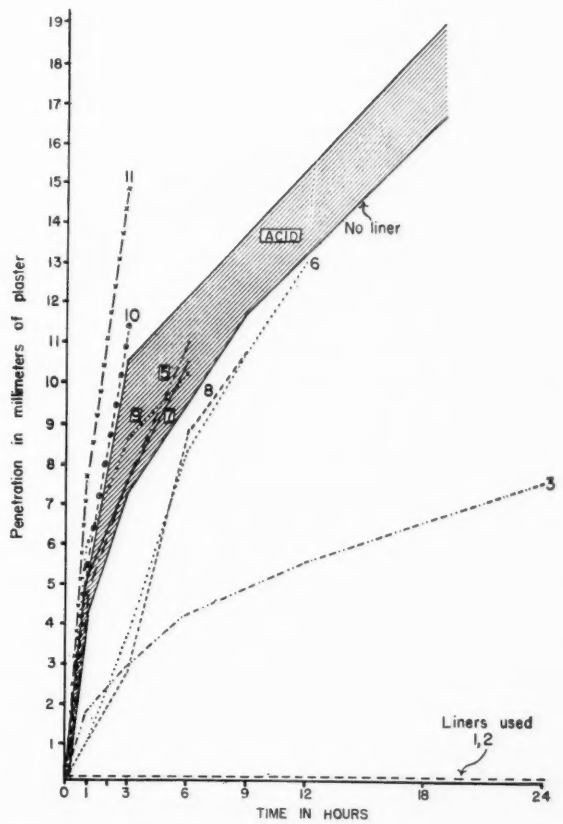

Fig. 12.—The graph shows the ineffectiveness of most liners when placed under phosphoric acid liquid (bromthymol blue indicator, pK 7).

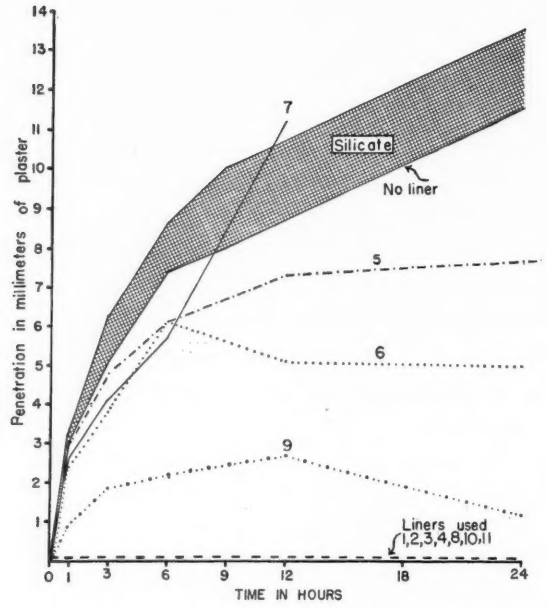

Fig. 13.—The graph shows the effectiveness of most liners when placed under a silicate cement (bromthymol blue indicator, pK 7). Compare with Fig. 7.

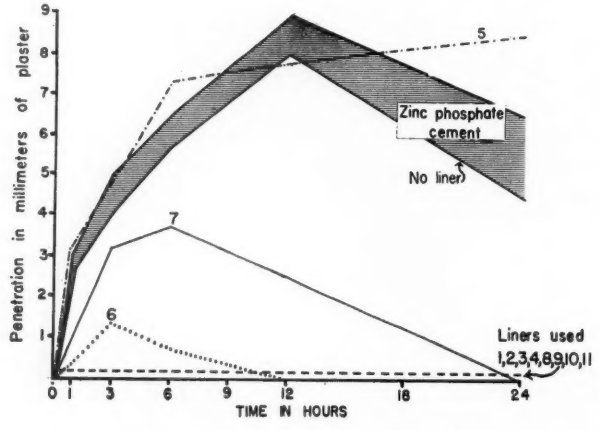

Fig. 14.—The graph shows the effectiveness of most liners when placed under a zinc phosphate cement (bromthymol blue indicator, pK 7). Compare with Fig. 8.

All liners except Nos. 5, 6, 7, and 9 were effective in preventing acid penetration under silicate cement (Fig. 13). Comparison with Fig. 7 shows that using bromthymol blue as the indicator, liners No. 6 (Chembar) and No. 9 (Pulpdent Liquid) are added to No. 5 and No. 7 as not being effective under silicate cement, the former because of frequent cracking and shrinkage, the latter because of the thinness of the film. Pulpdent Liquid appeared to be effective up to pH 4.7 but not to pH 7.

Under zinc phosphate cement, liners Nos. 5, 6, and 7 proved ineffective, as before (compare Figs. 14 and 8).

Comparison of data obtained using bromcresol green (pK 4.7) and bromthymol blue (pK 7) suggested that the latter provides a more severe test for the liners since the pH must return to neutrality before the penetration stops and the blue color returns. Although bromthymol blue is a more sensitive indicator of effectiveness, the color is weak and the end point more difficult to measure. We prefer bromcresol green as the indicator and the potentially damaging pH level of 4.7 in preference to bromthymol blue and the level of neutrality (pH 7).

SUMMARY AND CONCLUSIONS

An in vitro method of comparing the effectiveness of various liners and bases under silicate and phosphate cements has been presented. The method is simple and reproducible and is intended for the preliminary screening of new liners prior to bioassay or clinical testing in vivo.

The study showed that almost all of the liners tested effectively prevented the penetration of acid from the silicate and phosphate cements into the underlying area. Fast-setting zinc oxide and eugenol mixtures were most effective but have the disadvantage of discoloring the silicate cement. Copal resin varnish and a silicone were least effective. Chembar and Pulpdent Liquid were somewhat erratic in that the film produced was too thin and tended to crack easily.

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THE MICROSTRUCTURE OF NORMAL AND SCLEROSED DENTINE

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WITHIN A YEAR AFTER ROENTGEN'S ANNOUNCEMENT of his experiments with x-rays, this new form of energy was used by Morton[1] to compare the relative opacities of film images of soft tissues, bone, dentine, and enamel to determine the loss of calcific material caused by dental disease. Applebaum, Hollander, and Bodecker[2] first used x-rays to study the degree of mineralization of tooth tissues. Van Huysen and colleagues[3] pointed out in a precise microscopic x-ray absorption study that normal and abnormal areas of dentine in the same tooth have different total x-ray absorption. Since then, and particularly in the past decade, methods have been developed for study of the normal and abnormal mineralization of dentine by use of x-ray micrographic methods.

Engstrom, Cosslett, and Pattee[4] have recently edited an excellent review of the subject of x-ray micrography, describing appearance and densities of many body tissues, both calcified and uncalcified.

Miller[5] showed x-ray micrographs of dentine similar to those in Fig. 3 of the present study. The dentinal tubules appeared as dark, x-ray translucent centers with bright, x-ray opaque rings about them. The intertubular calcified matrix had an opaqueness to x-rays that appeared as a shade of gray between that of the black tubule center and its surrounding bright ring. It was Miller's opinion that the x-ray opacity of the peritubular area was a normal feature of dentine.

Bergman and Engfeldt[6] showed x-ray micrographs of dentine from a carious tooth. Again the cross-cut dentinal tubules appeared as small, dark or x-ray translucent areas. Many of the tubules showed bright or x-ray opaque margins of varying thickness, while some appeared completely x-ray opaque as though obliterated by mineral salts. It was their opinion that the x-ray translucent tubules with bright, x-ray opaque rings represented forms transitional between unaffected and obliterated tubules.

Rockert[7] also showed x-ray micographs of dentine from noncarious teeth. He stated that the peritubular x-ray opacities indicated increasing obliteration of dentinal tubules which was correlated with increasing age of the individuals from whom the teeth were obtained.

Blake[8] compared photomicrographs and x-ray micrographs of dentine. This comparison showed that peritubular light, translucent areas of dentine are also

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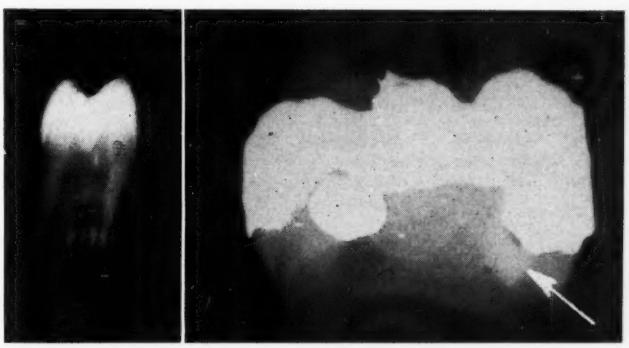
x-ray opaque. He believed that these margins are free of any organic matrix and become calcified after the collagen intertubular matrix has been formed.

It is the purpose of this study to compare x-ray micrographs of normal and sclerosed dentine.

MATERIAL AND METHODS

Planoparallel histologic sections 30 μ thick were prepared by grinding undecalcified dentine from the following teeth: an unerupted first premolar with 50 to 75 per cent complete root formation (Fig. 1, *A*), removed from a youngster for orthodontic reasons, and an exfoliated deciduous tooth crown (Fig. 1, *B*) which in



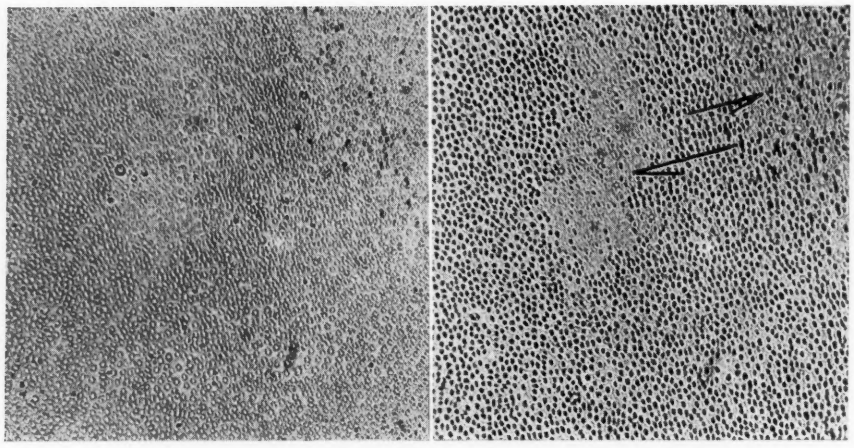
A. *B.*

Fig. 1.—*A*, An x-ray image of an unerupted premolar used as an example of normal dentine. *B*, An exfoliated deciduous crown with an arrow pointing to an area of sclerosed dentine. (× 4.)

the clinical x-ray film showed (see arrow) dentine sclerosis between the filling and the pulp chamber shadow.[9] The roentgenograms made with a conventional clinical x-ray machine and periapical dental film serve as a record of the original specimens.

The tooth crowns were ground with a revolving wet carborundum wheel until all of the enamel was removed. A thin steel circular saw was used to remove several (two to five) ½ mm. thick sections of coronal dentine. In the unerupted premolar, these relatively thick sections were cut through the crown parallel to and between the ground, flat occlusal surface and the pulp horns; in the deciduous tooth, they were cut through the area of sclerosis (marked by the arrow in Fig. 1, *B*) and perpendicular to the direction of the dentinal tubules from the pulp horn to the cavity base. Each section was then reduced to a thickness of 30 $\pm$ 1 μ and made planoparallel with finger pressure and a levigated alumina slurry on a glass plate. Final surface grinding and polishing were accomplished with an Arkansas stone and water as the wetting agent.

In the first part of the study, the ground sections of dentine were photomicrographed using transmitted light and at a magnification of the order of 300 diameters. The photomicrograph of dentine from the exfoliated tooth is illustrated



A. *B.*

Fig. 2.—Two photomicrographs, with the microscope focused on the lower surface *(A)* and on the upper surface *(B)* of the ground section of dentine. The arrow in *B* shows sclerosed surrounded by unchanged dentine. (× 300; reduced ¼.)

in Fig. 2, where the dentinal tubules appear in cross section, perpendicular to the ground surfaces of the section and slide. All sections were thin enough that the secondary tubule curvature was hardly noticeable.

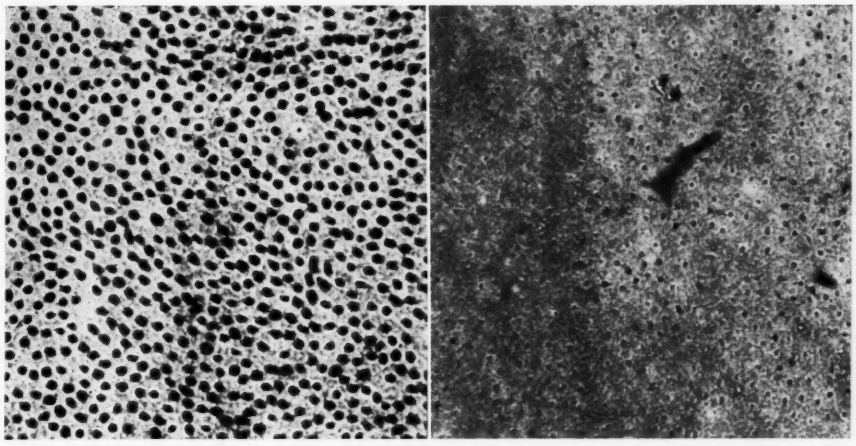
For the second part of this study, both of the ground sections referred to above were removed from the glass slides and x-ray micrographs of the sections were prepared as follows:

A Phillips (CMR) low voltage x-ray generator and Eastman fine-grained spectrographic film type 649-0 were used to make a contact x-ray image of the sections. These contact roentgenograms were then enlarged about 400 diameters photomicrographically to make the x-ray micrographs shown in Figs. 3, *A* and *B*, and 4.

OBSERVATIONS

With Photomicrographs.—Although this study concerns itself mainly with x-ray micrography of young, unaffected and of sclerosed dentine, as was pointed out above, photomicrographs of the ground dentine sections were made. Fig. 2, *A* and *B*, shows two photomicrographs made from the exfoliated deciduous molar (Fig. 1, *B*) through the sclerosed area of the ground section. Since these photomicrographs show unchanged as well as sclerosed dentine, it was not thought necessary to include a photomicrograph of the dentine from the unerupted premolar tooth shown in Fig. 1, *A*.

While preparing the photomicrographs of the ground histologic sections of dentine, it was apparent that slight differences in the focusing of the microscope produced the optical illusion known as the "Becke" effect.[10] This effect, though not generally recognized by dental histologists, has been pointed out before by Salter[11] as an artefact and results from relative refringence of the inorganic phase



A. *B.*

Fig. 3.—The photomicrographically enlarged contact x-ray of young dentine near the pulp *(A)* and at the periphery *(B)* of the dentine. (× 400; reduced ¼.)

of the dentinal tubule border. With the microscope objective focused on the lower surface of the ground section, the dentinal tubules appeared with bright centers surrounded by a dark peripheral ring as seen in Fig. 2, *A*. As the microscope objective was moved up from this position in order to focus higher on the tubules, the light coming through the centers of the tubules seemed to move centrifugally across the border out into the dentine matrix. This resulted in tubules with dark centers surrounded by bright rings as illustrated in Fig. 2, *B*.* This changing effect makes true delineation of the tubular microanatomy in undecalcified sections of dentine difficult. One cannot, for instance, call the dark tubular borders in Fig. 2, *A*, Neumann's sheath or the dark centers in Fig. 2, *B*, shrunken dentinal fibers. These relative refringence effects obscure the real view of the tubule margins.

In the approximate upper center of Fig. 2, *A* and *B*, one can see marked by the arrows an apparent obliteration of the dentinal tubule structure. This area is more light translucent, that is, fewer tubules are visible here than in the greater part of the slide. It is assumed that, since the dentine was removed from an area of clinically demonstrable sclerosis, it represents a histologic picture of this dentine change. The histologic structure of dentine from the unerupted tooth is essentially the same as the unchanged dentine shown in Fig. 2, *A* and *B*. The Becke effect shows up clearly in unchanged dentine. A photomicrograph of the normal dentine

*When ordinary illumination is transmitted by a mounted ground dentine section with the tubule walls perpendicular to the slide, the rays of low obliquity to the tubule boundary, instead of being reflected and transmitted by the mounting media of lower index of refraction, will be transmitted across the boundary into the dentine with its higher index of refraction and transmitted by the marginal dentine to the eye. Thus, with the microscope focused on the lower part of the section, before a relatively large proportion of the light rays can cross the tubule boundary, the center of the tubule will appear light, the borders relatively dark; when the microscope is focused high on the section, most of the light entering the tubules will have crossed the tubule boundary and will have been transmitted along the immediate boundary of the tubule to the eye by appropriate refractive activity of this calcified material.

from the unerupted premolar is not shown. It is obvious that sclerosis of dentine appears translucent to light, that is, there is an obliteration of the anatomic elements. Other than this, light does not show the degree of increased calcification in the dentine.

With Light.—The second part of this study shows x-ray micrographs of the same young and sclerotic dentine ground sections observed with light. The dentinal tubules in the x-ray micrographs of the ground section of dentine from the unerupted tooth appear in Fig. 3, *A* and *B*, as dark, x-ray translucent centers. These are surrounded by narrow, x-ray opaque, bright rings of variable widths, regularly spaced in an intermediate shade of gray background, typical of x-ray images of calcified dentine matrix. Miller[5] believed that peritubular x-ray opacity represents a normal feature of dentine. Blake[8] suggested that although these margins are free of any organic matrix, they are calcified, a process that takes place after the collagen intertubular matrix is formed and calcified. Since calcification without a matrix of some kind does not ordinarily occur in Nature, the inorganic phase of peritubular x-ray opacities needs further investigation.

Because of the known illusory tubular and peritubular optical effects, such as the Becke effect described above and seen in the photomicrographs, careful consideration was given the bright peritubular rings seen about the tubules in the x-ray micrographs. The possibility that the peritubular bright rings in the x-ray micrographs might represent a negative reversal processing effect or the "Mackie" or "Bragg" effect was, however, discounted. No other optical or processing illusory effect could be postulated at this time.

Fig. 3, *A*, shows relatively large, more numerous tubule openings, with a lesser degree of peritubular x-ray opacities than seen in Fig. 3, *B*. The former

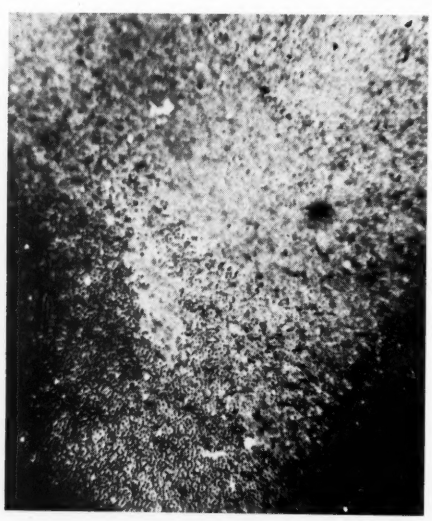


Fig. 4.—Photomicrographic enlargement of the contact x-ray image of the sclerosed dentine. (× 400; reduced ¼.)

represents dentine close to the pulp chamber, the latter out near the dentine periphery. X-ray opaque or obliterated dentinal tubules are also more numerous in the peripheral dentine than near the pulp chamber. This latter observation would lead one to believe that peritubular hypercalcification occurs throughout the dentine soon after its formation, but that obliteration of the tubule takes place from the periphery toward the pulp chamber.

In Fig. 3, *B,* one can also see the x-ray image of an interglobular space. The fact that this area of x-ray translucency shows no marginal x-ray opacity, as do the dentinal tubules, leads one to believe that peritubular x-ray opacity is an indication of hypercalcification and not an illusory x-ray or processing effect.

Fig. 4 shows an x-ray micrograph made of an area of clinically and histologically demonstrable sclerotic dentine, shown in Figs. 1, *B,* and 2, *A* and *B,* respectively. In the x-ray micrograph which represents a magnification of the order of 400 diameters, the arrows indicate a small and large area of irregular x-ray opacity. Examination of the margins of these areas of x-ray opacity seems to show that they are formed by extension and confluence of the peritubular x-ray opacities into the intertubular dentine matrix area, with obliteration of most of the tubules in the areas of more intense sclerosis.

In considering both the x-ray micrographs of young dentine and that of the sclerosed dentine, it would seem that dentine develops peritubular calcification shortly after its formation. Apparently, obliteration of the tubule with mineral salts takes place from the periphery of the tubule, that is, from the dentinoenamel margin, and progresses centripetally along the tubule toward the pulp chamber. Under stimulus from outside irritation, small and large foci of sclerosis extending from the peritubular calcification spread into the adjacent matrix.

SUMMARY AND CONCLUSIONS

The study has shown semiquantitatively the differences, at a microscopic level, between the calcification of normal dentine of a normal or an unerupted tooth and clinically demonstrable sclerosed dentine. It is interesting to note that sclerosis seems to be an extension of normal peritubular calcification peripherally out into the intertubular matrix. Tubule obliteration may occur without sclerosis. Confluence of peritubular extension of calcification will form relatively large areas of matrix hypercalcification or sclerosis.

It is also apparent that sclerosed dentine is more translucent to light than normal dentine. Transmitted light, however, is of limited value in determining increased calcification of dentine. X-ray micrography can be used for qualitative and quantitative estimation of dentinal sclerosis.

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SURGICAL PROSTHESIS

PROSTHESIS AFTER MAXILLECTOMY

A Case Report

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THE OPPORTUNITY FOR DENTISTRY to assume its place on the professional or health team is evident in this report. A prosthesis was needed after a radical surgical operation necessitated by a pathologic growth of tissue involving dental structures. The further development of the dentofacial complex, the restoration of oral function, including speech, and the improvement of appearance were dental factors to be considered.

DIAGNOSIS AND SURGICAL OPERATION

The patient, a 4-year-old Negro girl, was referred by a pediatrician to an otolaryngologist because of a large swelling on the left side of the face, presumably the result of a traumatic injury. A hard prominence was present in the maxillary region near the nose. Roentgenographic findings indicated a growth in the proximity of the left maxillary sinus.

The patient was admitted to the hospital, and a biopsy of the left maxillary antrum was made by the Caldwell-Luc approach. The biopsy diagnosis made by the Armed Forces Institute of Pathology was that of osteoid osteoma with aggressive growth tendencies.[1-7]

After the biopsy report, the patient was readmitted to the hospital and a hemimaxillectomy was performed (Fig. 1). Postoperative recovery was uneventful, and the patient was kept under combiotic therapy and tube fed for the first 5 days. On the sixth day, the first packing was removed and a rubber sponge shaped, fitted, and inserted to occlude the orifice and permit further healing of the margins of the tissue involved in the operation.

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CONSTRUCTION OF THE PROSTHETIC APPLIANCE

A complete roentgenographic and oral examination was performed at the dental clinic approximately 3 months after the surgical operation. All primary teeth were present except the upper left lateral incisor, cuspid, and molars, which were sacrificed in the operation. Extensive caries was present in several remaining teeth; a stainless steel crown was placed on the lower right second primary molar, and the lower left second molar was removed.

Fig. 1.

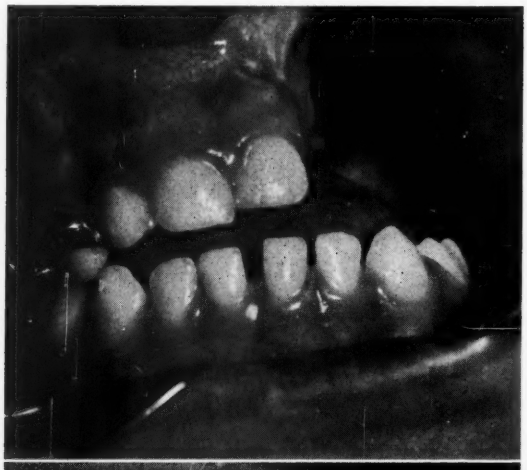

Fig. 2.

Fig. 1.—The oral cavity after left hemimaxillectomy and healing. Note the orthodontic bands with the retention lug on the cuspid and second deciduous molar.

Fig. 2.—The completed prosthesis in position. The right side shows the clasp engaged above the retention lug on the cuspid band.

The operative dental work was completed, alginate (irreversible hydrocolloid) impressions were made, and the study casts were mounted on the articulator. To facilitate making the upper impressions, the cavity created by the removal of the left maxilla was packed lightly with gauze saturated with petroleum jelly. The

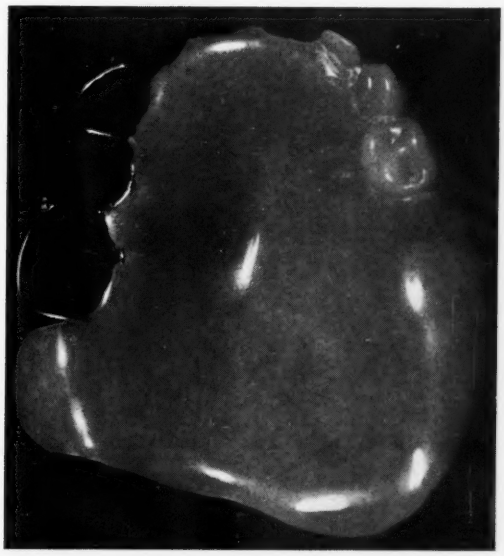

Fig. 3.—The completed prosthesis. Note the notch on the lingual side of the molar clasp which will engage on the retention lug on the lingual side of the molar band.

gauze created a surface which helped to shape the alginate impression material and gave definition to the borders of the defect. A string was fastened to the gauze pack and brought to the outside of the mouth to prevent displacement or swallowing of the pack.

Since anchorage or retention in stabilizing the prosthesis would be unilateral, the upper right first and second primary molars and cuspid were banded, with 0.006 inch gold orthodontic band material used on the molars and 0.004 inch material on the cuspid (Fig. 2). Retentive areas were created on the labiogingival surface of the bands of the cuspid and second molar and on the lingual surface of

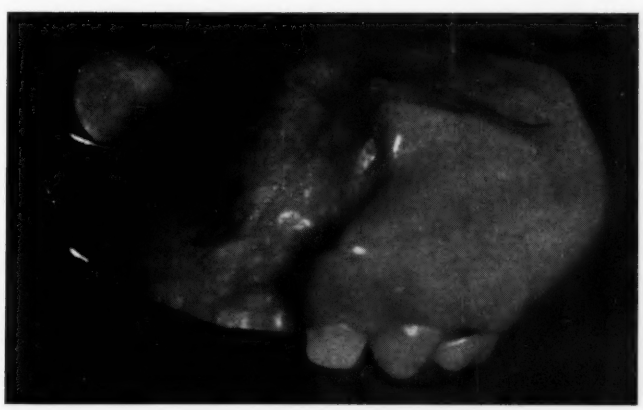

Fig. 4.—The completed prosthesis shows the obturator effect on the left side.

the two molars. The lugs for retention were made by soldering a piece of 0.028 inch round wire to the labial and buccal surfaces of the bands and modifying the solder seam on the lingual surface of the molar bands.

Clasps made of 0.028 inch stainless steel wire were fashioned to engage the retaining lugs on the lingual surface of the molars, the labial surface of the cuspid, and the buccal surface of the second molar. Thus, when the prosthesis was inserted, it was locked in place by the rest on the lingual surface and the retaining arm of the clasp on the buccal surface.

In order to secure an accurate adaptation of the denture base to the soft tissue and to provide a firm base in development of the occlusion, an acrylic resin–base occlusion rim was constructed. Soft modeling compound was added to the occlusion rim, and it was carried back into the mouth and recontoured on the cheek side for esthetic appearance. The casts were mounted on the articulator with the face-bow, the occlusion developed, and the prosthesis completed in the routine manner used for partial dentures (Figs. 3 and 4). The bands were cemented on the teeth, and the prosthetic restoration was adjusted to the teeth and soft tissue.

The patient adapted to the situation readily and without difficulty. Through the effective cooperation of the mother and child, the insertion and removal of the prosthesis for frequent cleansing have not been a problem. The speech is unintelligible without the removable partial denture, but with the denture in place, the patient can enunciate clearly and effectively. This patient will be observed to note the effect of the surgical operation on the further development of the dentition and facial structures.

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NONTYPICAL PROSTHESIS OF THE EAR

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A PATIENT WITH BILATERAL LACK OF EARS is considerably rare.[1] The ears of this patient were lost as a result of burns from flaming gasoline in an industrial accident.

PROCEDURE

The sculpture was indirect, the ears of the patient's brother being used as a guide.[2] Impressions of the ears were made with alginate (irreversible hydrocolloid) impression material. The molds thus obtained were applied as well as possible to the lesions in a model of the head of the patient. Holes were made in the posterior parts of the alginate impressions, and melted wax was poured into the impression through these holes. Rectangular "extensions," directed upward, were added to the wax models thus obtained. Acrylic resin with an intrinsic pigmentation obtained with mineral powders was used for the prosthesis.

In the finished prosthesis, the extensions were attached to the thick temple pieces of glasses by means of self-curing acrylic resin. A slight support in the

Translated from Portuguese by Dr. Dioracy Fonterrada Vieira.
*Assistant Professor.

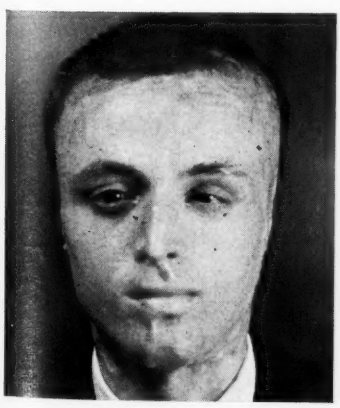

Fig. 1.

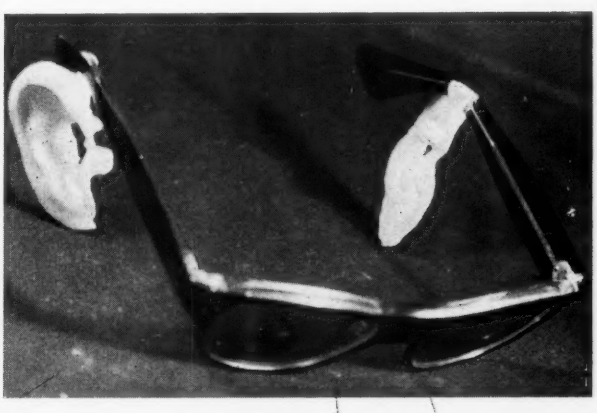

Fig. 2.

Fig. 1.—The patient lost both ears as a result of gasoline burns.
Fig. 2.—The completed ears are attached to the temple pieces of glasses with cold-cure acrylic resin.

Fig. 3. Fig. 4.

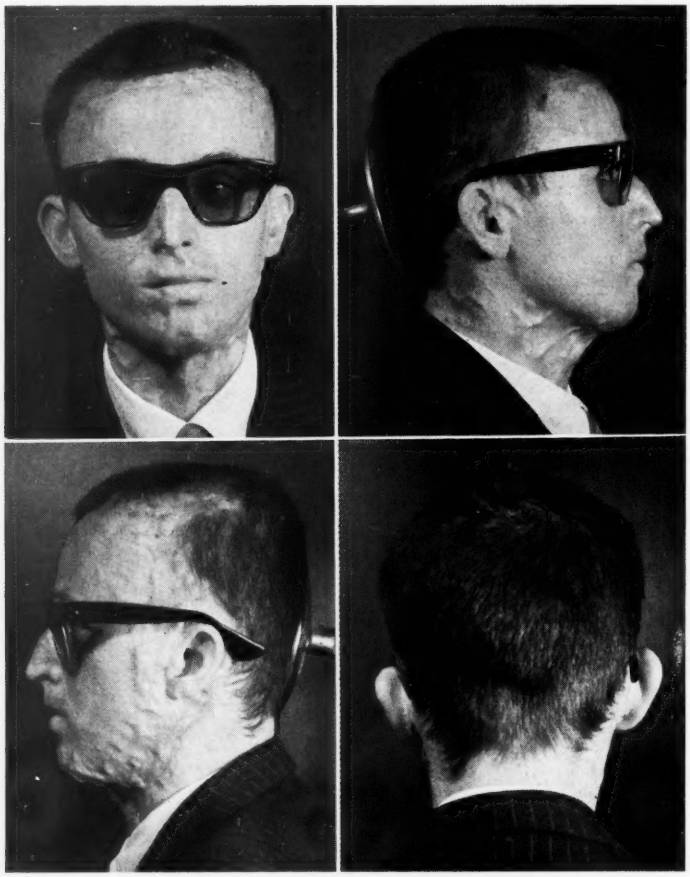

Fig. 5. Fig. 6.

Figs. 3 to 6.—The ears are supported by the glasses, a sheet of elastic rubber, and small support in the auditory canal.

auditory canal prevented vertical movement of the artificial ears. A rubber strip joining the distal part of the glasses completed the retention system of the prosthesis (Figs. 1 to 6).

SUMMARY

A bilateral ear prosthesis is described. The retention is supplied by the temple pieces of glasses, a slight vertical support in the auditory canals, and a sheet of elastic rubber behind the head.

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MISCELLANEOUS

THE RELATIONSHIP BETWEEN THE CARDIOLOGIST AND THE PROSTHODONTIST

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As a cardiologist, I wish to discuss the relationships between our two specialties. Before preparing this lecture I had no idea how far the profession of dentistry had gone toward specialization. The Dean of New York University College of Dentistry was kind enough to tell me that there are seven areas of approved specialization: orthodontics, oral surgery, oral pathology, public health dentistry, periodontics, pedodontics, and, of course, prosthodontics.

Similarly, internal medicine is also broken down into cardiology, gastroenterology, etc., each with its subspecialties—cardiology is further divided into pediatric cardiology, peripheral vascular disease, and cardiac surgery, and no doubt there will be additional subspecialties in the future.

Despite the fairly universal suspicion that concentration in a limited area of skill is dangerous, it has been concluded that specialism and the "pursuit of excellence" do go hand in hand.

HISTORICAL BACKGROUND

Relationships between cardiology and dentistry have a long historical background. When I first began to practice, it was felt that in any obscure derangement of the heart, foci of infection should be sought. It was also believed that periodontal disease furnished a focus for absorption that might be reflected in the heart or at least could cause myocardial disease. That concept, not fully proved or disproved, is not commonly believed today. It is fair to say that infected teeth are rarely a cause of myocardial disease; there are many sources of infection besides the teeth, and the cure and care of the heart patient must depend on many other causes of heart disease. (When teeth are interfering with general health, of course, there is no question of the importance of their care.)

That an individual with cardiac valvular disease may develop an infection on one of the valves after dental extraction has been known for some time. During

Read before the American Denture Society in New York, N. Y.

the beginning of my practice, such a patient was granted no chance for survival. Now, however, the infection can be prevented, and the dreaded condition known as bacterial endocarditis can be cured.

Besides the need for dental care among the young, the prosthodontist and the cardiologist concern themselves primarily with patients of the age at which arteriosclerotic heart disease is common.

The experienced dentist is often in a strategic position to suspect the presence of heart disease, and certainly before undertaking any major procedures, he will want to know that the patient at least has a negative history regarding the presence of cardiovascular disease; here, close cooperation with the physician is of extreme importance. (The cardiologist should also have some training in the fundamental principles of nonmechanistic phases of dentistry.) Besides learning a patient's history, the dentist is also in a position to observe pulsations of the carotid arteries or jugular veins which might indicate underlying cardiac disease. He might even recognize the early signs of cardiac failure, although he certainly does not have to make the diagnosis of cardiovascular disease.

PAIN IN THE JAW RESULTING FROM CORONARY HEART DISEASE

Often, patients with pain in the jaw resulting from coronary heart disease consult their dentists before they consult their physicians. One reported instance follows.

A 43-year-old man noticed a throbbing, aching, localized pain at the angle of the left side of the mandible. This discomfort increased in severity over a 24 hour period, and the patient, thinking he had an abscessed tooth, consulted his dentist. A careful examination revealed no cause for the pain. The patient continued to have severe pain in the same region during the next 48 hours, and a dental consultant was called. Another careful examination and additional roentgenograms disclosed no pathologic condition. Eventually the patient noticed chest discomfort and consulted his physician. A heart attack was suspected and was confirmed by the electrocardiogram.

In other words, when bizarre jaw pain occurs associated with chest or arm discomfort and when careful oral examination and roentgenograms fail to demonstrate a pathologic dental condition, coronary artery disease should be considered.

A dentist who came under my care experienced just such pain and described it to me as follows.

"Pain, not too intense, involved the mandible, mandibular teeth and gums, parotid areas, and upper and left molars. The episodes of pain took place on walking and often after a meal. There was feeling of having overeaten. In the early phase, the pain radiated to the neck only, below the sternocleidomastoid muscles, and ceased almost instantly upon cessation of walking. Later, when the pain involved the fascial envelope of the chest, it persisted even though walking was stopped. The attacks were initiated upon average exertion and excitement. There was a debilitating feeling. The pain was relieved by rest, analgesics such as aspirin, and antacids."

This description of the patient's attacks of pain exactly as they occurred is of great interest, especially since the individual proved to have coronary insufficiency.

Thus, the prosthodontist is occasionaly in a position to suspect cardiac disease. When he has such a patient, there are certain areas of his work in which he can be of help.

ANXIETY

It has now been firmly established that the emotions can have a profound effect upon cardiac patients. How profound this effect can be has not been fully recognized. The heart rate and rhythm can be changed. The cardiac output can be increased. The blood pressure can be affected, and there is some evidence that the pattern of the electrocardiogram can be influenced. Most workers agree that anxiety has an effect on the circulation similar to that produced by a small dose of epinephrine.

The effect of emotion on the circulation is of such extreme importance that the prosthodontist must recognize it and do all that he can to control anxiety. Particularly for cardiac patients, much depends upon the approach. A proper explanation of what is going to be done, how long it is going to take, how much pain the patient will have—just a few minutes' explanation—will prove worth while. This explanation may even be more important than the use of sedative drugs. Nevertheless, when antianxiety drugs are indicated, they should be used.

ARRHYTHMIAS

The cardiologist is concerned about the various changes in rhythm that may occur in patients with known coronary disease. By proper management of anxiety and pain and by drug utilization (avoiding the use of adrenalin and atropine), much can be done to control and lessen myocardial irritability so that the chances of changes in rhythm are not too great. The occurrence of one of the paroxysmal arrhythmias, such as auricular fibrillation or flutter, or one of the tachycardias, such as auricular or conceivably ventricular, constitutes a special problem in which treatment should be only supportive until proper therapy can be administered.

PAIN

While anxiety can be allayed by the proper approach to the patient, no amount of conversation will relieve pain. The control of pain in the cardiac patient is most important, and close cooperation between the cardiologist and the dentist is certainly indicated. If pain is not controlled, the heart rate may be increased; the resulting increased load on a possibly already impaired coronary circulation may bring about coronary insufficiency with angina pectoris or myocardial infarction. In a patient with severe mitral disease, such an increase in heart rate might result in an attack of pulmonary edema.

The dentist is the best judge of the type of anesthetic to be used, whether local or general. In coronary disease, epinephrine is usually prohibited as an anesthetic, since it will increase the heart rate and cause myocardial irritability. Some patients are adversely affected by the stimulation to the central nervous

system that procaine may produce. When dental surgical operation is necessary in a cardiac patient, hospitalization of the patient might be considered. General ether anesthesia with oxygen is considered to be very safe for most cardiac patients. Intravenous barbiturates are used and appear to be safe in the hands of experienced anesthetists.

In general, if any surgical operation must be done, it should be done at one time, rather than in several operations with the attendant danger of repeated use of anesthetics.

Causes of Pain Other Than Surgical Operations.—Pain, while usually associated with a surgical procedure, can also result from other dental factors, such as ill-fitting dentures. This could produce an anginal syndrome or a myocardial infarction in a patient with coronary disease. Recently, one dentist reported the case of a cardiac patient in whom poorly fitted dentures caused constant irritability, nervousness, and insomnia; all of these factors may precipitate a coronary accident.

BLOOD PRESSURE

Blood pressure is usually not a problem, except in connection with anesthesia, with which hypotension may occur. Such occurrences fall directly within the realm of the anesthetist.

However, a relatively new problem has arisen with the growing use of long-term anticoagulants. Although still a somewhat controversial subject, the use of long-term anticoagulants in patients who have had myocardial infarctions has been increasing. Many cardiologists believe that continuation of anticoagulant therapy over a period of years improves prognosis in coronary artery disease.

In any event, that a patient has been on anticoagulants and that such treatment is continuing must become known to his dentist if serious bleeding, even from trivial injury, is to be avoided. One complicating factor is that sometimes the patient himself is not aware that he is being given anticoagulants.

INFECTION

More and more patients are surviving into the age group in which prosthodontic treatment may be a necessity. Since the possibility of bacterial endocarditis after dental extraction is not confined to young individuals but occurs as well in later life, we are increasingly concerned with arteriosclerotic patients who may have concomitant valvular heart disease.

Penicillin is the antibiotic commonly used in the prevention of bacterial endocarditis. Newer and possibly better antibiotics may be available soon. A proper penicillin level must be maintained for a long enough time to be effective.

ANGINAL ATTACK AND NITROGLYCERIN

The arteriosclerotic patient is always subject to the possibility of an anginal attack. Nitroglycerin is still the most effective drug in the treatment of angina pectoris. No harm is seen in the prophylactic use of nitroglycerin in a patient who is known to have coronary disease and who may be subjected to stress.

In my opinion, a very small dose of nitroglycerin (1/250 gr.) in the form of a gelatin-covered capsule that can be crushed between the teeth is the most effective way to administer nitroglycerin. When nitroglycerin is not available immediately, whiskey sometimes can prove effective in the control of anginal pain.

MYOCARDIAL INFARCTION DURING SURGICAL OPERATION

In spite of the most careful management, myocardial infarction does occur with anesthesia. Should it result either from anesthesia or surgical shock, it would not be difficult to recognize the subjective symptoms immediately. These include paroxysmal thoracic pain and a sense of impending suffocation and death. There may also be evidence of shock, perspiration, vomiting, low blood pressure, and a thready pulse.

While nitroglycerin will relieve anginal pain, it will have no effect or perhaps even a harmful one where myocardial infarction has occurred. In such cases, the patient should be maintained in a quiescent state and pain should be alleviated (Demerol is an effective drug) until he can be removed to the nearest hospital.

CARDIAC STANDSTILL

The dentist, like any other surgeon, may be faced with the tragedy of cardiac arrest or standstill. In such cases, unless the patient is in a hospital, probably not much can be done to deal effectively with the situation. Fortunately, this catastrophe is very rare.

NUTRITION

The cardiac patient who has been in heart failure, for example, is subjected to all kinds of treatment which may interfere with his proper nutrition. He is given drugs, such as digitalis, which may and frequently do destroy the appetite, even with the most careful management. Other cardiac drugs such as quinidine and theobromine may have the same effect. In addition, with the increased use of many of the diuretics, such as the mercurials, and the various new preparations, such as chlorothiazide, the patient is constantly "washed out," with marked disturbances in the balance of his nutritional state. Many of these patients are put on a salt-free diet which, even with the use of salt substitutes, is far from appetizing.

The cardiologist, therefore, is particularly concerned with the importance of proper dentures for his patients. Any means to improve the desire to eat, including proper dentures with which to chew, is of extreme value in the management of these patients.

Only recently I saw a patient with heart failure and with a relatively severe anemia in whom the lack of proper dentures played an important role. Despite having an adequate income, this woman possessed extremely bad teeth, and she was therefore unable to chew and enjoy her food. While not the entire problem by any means, her dental condition pointed to the proper cooperative effort to be made by the dentist and the cardiologist toward improving the state of her health.

SUMMARY AND CONCLUSIONS

Relationships between the cardiologist and the prosthodontist have a long historical background. The experienced dentist is often in a strategic position to suspect the presence of heart disease; before undertaking any major procedures, he will want at least to have a negative history regarding the presence of cardiovascular disease. Often, patients with pain in the jaw caused by coronary heart disease consult their dentists before they consult their physicians. Once cognizant that he is faced with the management of a patient with coronary disease, there are several areas in which the dentist can be of assistance to his patient, including: alleviation of anxiety by an explanation of the dental procedure to be undertaken; management of pain, in and removed from surgical procedures; determination of the patient's possible use of anticoagulants; the use of antibiotics, if necessary, in control of infection; knowledge of the use of nitroglycerin should an anginal attack occur; recognition of a myocardial infarction; and cooperation with the cardiologist to improve the nutritional state of the patient by proper dentures and dental care.

In addition, as Francis W. Peabody, one of the great young teachers and physicians in American medicine, expressed it some time ago:

"The practice of medicine [and dentistry] in its broadest sense includes the whole relationship of the physician [and dentist] with his patient. It is an art based to an increasing extent on the medical sciences, but comprising much that still remains outside the realm of science.

"The art of medicine [and dentistry], and the science of medicine [and dentistry] are not antagonistic but supplementary to each other. There is no more contradiction between the science of medicine [and dentistry] than between the science of aeronautics and the art of flying. One of essential qualities of the clinician and the dentist is interest in humanity, for the secret of the care of the patient is in caring for the patient."

I like to hear people speak of "my dentist" or "my physician," because in that they imply that the two professions that take care of them are sincerely interested in their welfare.

141 East 55th St.
New York 22, N. Y.

BOOK REVIEWS

INTERNAL MEDICINE IN DENTAL PRACTICE. By Leon H. Collins, Jr., A.B., M.D., F.A.C.P., F.C.C.P., and Martin P. Crane, B.S., M.D., Sc.D. (Hon), ed. 5, Philadelphia, 1960, Lea & Febiger. Pp. 555, 94 illustrations—30 in color, index, bibliography. Price $8.50.

This book is intended primarily to inform the dentist and dental student of the close relationship between certain mouth conditions and systemic diseases, or the influence of systemic diseases on patients who require dental therapeutics, so that the dentist can more intelligently offer recommendations relative to the need for consulting an internist, make scholarly reports to the patient's physician when required, govern his own procedures, and guard his own health and that of his family by the observations he makes.

The authors comment clearly and concisely on systemic diseases and point out their influence on oral structures. Of special interest to dentists are diseases of the heart, blood vessels, blood, and blood-forming organs and anemia and leukemia.

The section on infection, classification of the organisms involved, and suggested medication was gratifying to read.

Part XI, covering allergy, nutrition, and vitamins, was too short when one considers their importance to the health of the dentist and his patients. However, it was expertly condensed, and the oral manifestations of vitamin deficiencies were illustrated by six color plates, which somewhat nullified the preceding objection.

Numerous "Box Summaries," a unique feature and pleasant departure from the ordinary, glamorize the subject matter, focus the attention of the reader, and stimulate his interest in the material.

Boldface type and italics are used freely to emphasize important points, break the monotony of the printing, and hold the interest of the reader.

The facts that five editions of the book have been published since 1938 and that it is highly regarded by men in the dental specialties indicate its popularity.

In reading this book, one can sense the close correlation necessary between dentists and their medical colleagues. This book should be in all dental offices and libraries.

W. Russell Kampfer, D.D.S.

NEWS AND NOTES

MEETINGS

Canadian Dental Association, Ottawa, Canada, Sept. 25 to 28, 1960.

American Society of Oral Surgeons, Westward Ho Hotel, Phoenix, Ariz., Oct. 12 to 15, 1960. For further information write to Mr. D. C. Trexler, Executive Secretary, 840 North Lake Shore Dr., Chicago 11, Ill.

American Academy of Periodontology, Miramar Hotel, Santa Monica, Calif., Oct. 13 to 15, 1960. The theme of the scientific program is "The Role of the Tooth in Periodontal Health and Disease."

American Denture Society, Beverly Hilton Hotel, Los Angeles, Calif., Oct. 14 and 15, 1960.

American Society of Dentistry for Children, Ambassador Hotel, Los Angeles, Calif., Oct. 14 to 16, 1960.

American Academy of Maxillofacial Prosthetics, Sheraton-West Hotel (Sheraton Town House), Los Angeles, Calif., Oct. 20 to 22, 1960. For further information write to Dr. Mervin C. Cleaver, Executive Secretary, 2330 Linwood Ave., Apt. 3H, Coytesville, N. J.

Mid-Continent Dental Congress, Chase Hotel, St. Louis, Mo., Nov. 27 to 30, 1960. For further information write to the St. Louis Dental Society, 8013 Maryland Ave., St. Louis 5, Mo.

American Academy of Dental Medicine Midwinter Meeting, New York, N. Y., Dec. 4, 1960. For further information write to Dr. George F. Clarke, Secretary, 554 Franklin St., Melrose 76, Mass.

Greater New York Dental Meeting, Statler Hilton Hotel, New York, N. Y., Dec. 5 to 9, 1960. For further information write to Mrs. Mabel Purdy, Executive Secretary of the Meeting, Room 106A, Statler Hilton Hotel, New York 1, N. Y.

American Equilibration Society, Sheraton-Blackstone Hotel, Chicago, Ill., Feb. 2, 1961. For further information write to Dr. R. C. Van Dam, Secretary, 11431 South Halsted St., Chicago, Ill.

American Association of Endodontists, Conrad Hilton Hotel, Chicago, Ill., Feb. 2, 1961. For further information write to Dr. Edwin C. Van Valey, Secretary, 9 Rockefeller Plaza, New York 20, N. Y.

American Academy of Restorative Dentistry, Conrad Hilton Hotel, Chicago, Ill., Feb. 4 and 5, 1961.

American Academy of Crown and Bridge Prosthodontics, Conrad Hilton Hotel, Chicago, Ill., Feb. 4 and 5, 1961.

International Association for Dental Research, Hotel Statler, Boston, Mass., March 23 to 26, 1961. Abstracts of papers for presentation at the 39th Annual Meeting must be submitted on *special forms provided by the Association.* Additional forms may be obtained from Howard F. Campbell, Assistant Secretary-Treasurer, I.A.D.R., 2000 P St., N.W., Washington 6, D. C.

American Association for Cleft Palate Rehabilitation, Montreal, Canada, May 4 to 6, 1961.

Australian Dental Association, 16th Australian Dental Congress, Sydney, New South Wales, Aug. 14 to 18, 1961.

17th French Congress of Stomatology, Medicine College–Eastman Institute, Paris, Autumn, 1961. For further information write to the Secrétariat du XVIIième Congrés Français de Stomatologie, Institut de Stomatologie, 20 Passage Dauphine, Paris-6ième.

ANNOUNCEMENTS

Unfilled orders for reprints of the *Glossary of Prosthodontic Terms* will be filled as soon as reprints of the second edition are available.

Reprints of "Principles, Concepts, and Practices in Prosthodontics" may be obtained by writing Dr. W. Les Warburton, Secretary-Treasurer, Academy of Denture Prosthetics, 807 Medical Arts Bldg., Salt Lake City 11, Utah. The price is 25 cents per copy, with a 20 per cent discount allowed on purchases of 20 or more copies. Cash, check, or purchase order *must* accompany the order.

Reprints of the article, "The Microbiology of Plastic Dentures," by William W. Leathen, Norma A. Kinsel, Craig C. Brown, and William F. Swanson (J.A.D.A. 60:164-170, 1960), may be obtained without cost by writing to Mellon Institute, 4400 Fifth Ave., Pittsburgh 13, Pa.

AMERICAN DENTAL ASSOCIATION PROGRAM FOR DENTAL LABORATORY TECHNICIANS

A special program for dental laboratory technicians will be presented at 9:00 A.M., Thursday, Oct. 20, 1960, as part of the essay program at the American Dental Association's 1960 meeting in Los Angeles. The participants in the October 20 program and their subjects are as follows:

Moderator: J. Eugene Ziegler, Los Angeles, Chairman of the American Dental Association Council on Dental Trade and Laboratory Relations.

Occlusion in Complete Dentures: Clyde H. Schuyler, New York, Chairman, Committee on the Education and Certification of Dental Laboratory Technicians, American Dental Association Council on Dental Education.

Analysis of Newer Dental Materials and Techniques of Interest to the Dental Technician: Ralph Phillips, Indianapolis, Chairman and Professor, Department of Dental Materials, Indiana University, School of Dentistry.

Waxing of Full Reconstruction Cases: Charles E. Stuart, Ventura, California.

Panel Discussion.

Association President Paul H. Jeserich and NADL President Ugo S. Garganese will also participate in the special program.

Dental laboratory personnel who meet one of the following criteria and are registered at the 1960 meeting will be admitted to the October 20 program:

1. All certified dental laboratory technicians.
2. All dental laboratory technicians employed by licensed dentists.
3. Dental laboratory owners who are members of the National Association of Dental Laboratories.
4. Employees of NADL member laboratories.

The Lancaster Cleft Palate Clinic offers a seminar from Oct. 31 to Nov. 3, 1960, in diagnosis, research, and treatment of individuals with oral-facial-speech handicaps. Applications are available to the dental, medical, and speech professions.

For further information and application write to Dr. M. Mazaheri, Chief, Dental Services, Lancaster Cleft Palate Clinic, 24 North Lime St., Lancaster, Pa.

The University of California Extension Dental Program in conjunction with the American Academy of Implant Dentures is giving a 3 day clinic on Denture Implants at 815 South Hill St. in Los Angeles immediately preceding the 101st Annual Session of the American Dental Association.

The time will be from 9:00 A.M. to 4:00 P.M., Oct. 14 to 16, 1960. The clinic will include a closed circuit television presentation of actual denture implant operations on 2 patients. In addition, there will be various table clinics, seminars, and film presentations.

For further information contact University of California Extension Dental Program, Room 211, 815 South Hill St., Los Angeles 14, Calif.

POSTGRADUATE COURSES

The University of Alabama, School of Dentistry, will present the following refresher courses:

Root Canal Therapy, Nov. 5 to 7, 1960.

Major Oral Surgery, Nov. 12 to 14, 1960.

For further information and application write to the Director, Refresher Course Program, University of Alabama, School of Dentistry, 1919 Seventh Ave., S., Birmingham 3, Ala.

Boston University, School of Medicine, Division of Graduate Studies, Department of Stomatology, announces the following postgraduate courses:

Periodontal Therapy, Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Jack Bloom, and associates, Nov 7 to 11, 1960.

Fixed Bridge Prosthesis, Dr. Leo Talkov, Dr. David J. Baraban, and Dr. Lloyd Warshauer, Nov. 14 to 18, 1960.

Full Denture Prosthesis, Dr. Chester Landy, Dec. 12 to 16, 1960.

For further information write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospitals, 750 Harrison Ave., Boston 18, Mass.

Boston University, School of Medicine, offers 1 year courses in Oral Surgery and Endodontics and courses of 2 academic years in Orthodontics and Prosthodontics.

For further information concerning these courses write to Department of Stomatology, Boston University, School of Medicine, 80 East Concord St., Boston 18, Mass.

Loyola University, Chicago College of Dental Surgery, is offering a Research and Teacher Training Program in Oral Biology. This is under a Teacher Training Grant from the National Institutes of Health. It is designed for candidates who desire a teacher's career in basic sciences or in clinical subjects. The stipends are up to $5,000 per year, and the program can lead to an advanced degree.

For further information and application write to Dr. Harry Sicher, Director, Loyola University School of Dentistry, 1757 West Harrison St., Chicago 12, Ill.

New York University, College of Dentistry, announces the following postgraduate courses:

Endodontics, Dec. 1 and 2, 1960.

Complete Denture Participation, Jan. 16 to 20, 1961.

Immediate Dentures, Feb. 15 to 17, 1961.

Dental Obturators, March 15 to 17, 1961.

Partial Dentures, April 19 to 21, 1961.

For further information and application write to Director, Postgraduate Division, New York University, College of Dentistry, 421 First Ave., New York 10, N. Y.

The Ohio State University, College of Dentistry, announces the following postgraduate courses:

Current Concepts in Operative Dentistry, Dr. Donald Dickson and Dr. Harry Postle, Oct. 27 to 29, 1960.

General Anesthesia, Dr. Morgan Allison, Oct. 31 to Nov. 4, 1960, and May 15 to 19, 1961.

Complete Denture Prosthodontics, Dr. Carl O. Boucher, Nov. 7 to 11, 1960, and April 3 to 7, 1961.

Oral Surgery, Dr. Morgan Allison, Nov. 28 to Dec. 2, 1960, and May 22 to 26, 1961.

Elastic Impression Materials and Technics, Dr. Thomas McBride and Dr. Donald Dickson, Dec. 7 and 8, 1960.

Crown and Bridgework, Dr. Thomas McBride, Jan. 23 to 27, 1961.

A Refresher Course in Dental Hygiene, Dr. Consuelo Wise and Dr. John Wilson, Jan. 30 and 31, 1961.

Pedodontics and Interceptive Orthodontics, Dr. Lyle Pettit and Dr. Benjamin Williams, Feb. 20 to 24, 1961.

Endodontics, Dr. J. Henry Kaiser, March 6 to 10, 1961.

Hypnosis in Dentistry, Dr. Charles Pfersick, April 10 to 12, 1961.

Periodontics, Dr. John Wilson and Dr. William Walton, April 13 to 15, 1961.

Removable Partial Denture Prosthodontics, Dr. Victor Steffel, April 24 to 28, 1961.

Dental Drugs in Action, Dr. W. Russell Kampfer, May 19 and 20, 1961.

For further information and application write to the College of Dentistry, The Ohio State University, 305 West Twelfth Ave., Columbus 10, Ohio.

Temple University School of Dentistry announces the following postgraduate course:

Clinical Endodontics, Dr. Leonard Parris, Oct. 31 to Nov. 5, 1960.

For further information and application write to Dr. Louis Herman, Director of Postgraduate Studies, Temple University School of Dentistry, 3223 North Broad St., Philadelphia 40, Pa.

Tufts University School of Dental Medicine announces the following postgraduate courses:

A Special Participation Course in Periodontology, Oct. 31 to Nov. 4, 1960.

Newer Concepts for Inlay Construction, Nov. 15 and 16, 1960.

The Construction of the Full Crown, Jan. 16 and 17, 1961.

A Course in Periapical Surgery, Jan. 26 and 27, 1961.

Minor Oral Surgery, Wednesdays, March 1, 8, 22, and 29, April 5 and 12, 1961.

Clinical Adjustment of the Occlusion, May 3 to 5, 1961.

Applications are now being accepted for two Research Fellowships in Oral Pathology and Periodontology for the school year beginning September, 1960.

For further information and application write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

DIRECTORY

OFFICERS OF THE ORGANIZATIONS WHICH HAVE THE JOURNAL OF PROSTHETIC DENTISTRY AS THEIR OFFICIAL PUBLICATION

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Next Meeting: Conrad Hilton Hotel, Chicago, Ill., Feb. 4 and 5, 1961.

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Next Meeting: New York, N. Y., Dec. 3 and 4, 1960.

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Associate Editor: L. George Parry, 304 Medical Arts Bldg., 384 Peachtree St., N.E., Atlanta, Ga.
Next Meeting: Americana Hotel, Miami Beach, Fla., May 18 to 21, 1961.

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Executive Secretary: Mervin C. Cleaver, 2330 Linwood Ave., Apt. 3H, Coytesville, N. J.
Associate Editor: A. H. Bulbulian, 102 Second Ave., S.W., Rochester, Minn.
Next Meeting: Sheraton-West Hotel, Los Angeles, Calif., Oct. 20 to 22, 1960.

*Deceased.